January 2007

GIPSA Livestock and Meat Marketing Study

Contract No. 53-32KW-4-028

Volume 4: Hog and Pork Industries
Final Report

Prepared for

Grain Inspection, Packers and Stockyard Administration
U.S. Department of Agriculture
Washington, DC 20250

Prepared by

RTI International
Health, Social, and Economics Research
Research Triangle Park, NC 27709

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Abstract

Over time, the variety, complexity, and use of alternative marketing arrangements (AMAs) have increased in the livestock and meat industries. Marketing arrangements refer to the methods by which livestock and meat are transferred through successive stages of production and marketing. Increased use of AMAs raises a number of questions about their effects on economic efficiency and on the distribution of the benefits and costs of livestock and meat production and consumption between producers and consumers. This volume of the final report focuses on AMAs used in the hog and pork industry and addresses the following parts of the Grain Inspection, Packers and Stockyard Administration (GIPSA) Livestock and Meat Marketing Study:

- Part C. Determine extent of use, analyze price differences, and analyze short-run market price effects of AMAs.
- Part D. Measure and compare costs and benefits associated with spot marketing arrangements and AMAs.
- Part E. Analyze the implications of AMAs for the livestock and meat marketing system.

This final report follows the publication of an interim report for the study that used qualitative sources of information to identify and classify AMAs and describe their terms, availability, and reasons for use. The portion of the study contained in this volume of the final report is based on quantitative analyses, using industry survey data from producers, feeders, packers, processors, wholesalers, retailers, and food services, as well as transactions data and profit and loss (P&L) statements from packers and processors.

This volume of the final report presents the results of analyses of the effects of AMAs on the markets for hogs and pork products. Economic and statistical models were developed and estimated to examine the effects of AMAs on hog and pork prices, procurement costs, quality, price risk, and consumers

and producers. Results of analyses of the estimated effects of hypothetical restrictions on AMAs are also presented.

The principal contributors to this volume of the final report are the following:

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We would like to thank the anonymous peer reviewers and GIPSA staff who provided comments on earlier drafts, which helped us improve the report. We also thank Melissa Fisch and Sharon Barrell for editing assistance.

This report and the study on which it is based were completed under a contract with GIPSA, U.S. Department of Agriculture (USDA). Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of GIPSA or USDA.

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Executive Summary

As part of the congressionally mandated Livestock and Meat Marketing Study, this volume of the final report presents the results of analyses of the effects of alternative marketing arrangements (AMAs) in the hog and pork industries. This final report focuses on determining the extent of use of AMAs, analyzing price differences and price effects associated with AMAs, measuring the costs and benefits associated with using AMAs, and assessing the broad range of implications of AMAs. The analyses in this volume were conducted using the results of industry interviews; the industry surveys; and the analysis of individual packers' transactions data, individual packers' profit and loss (P&L) data, Mandatory Price Reporting (MPR) data, Agricultural Resource Management Survey (ARMS) data, and other publicly available data.

In this report, AMAs refer to all possible alternatives to the cash or spot market. AMAs include arrangements such as forward contracts, marketing agreements, procurement or marketing contracts, production contracts, packer owned, custom feeding, and custom slaughter. Cash or spot market transactions refer to transactions that occur immediately, or "on the spot." These include auction barn sales; video or electronic auction sales; sales through order buyers, dealers, and brokers; and direct trades.

The central focus of this report is the market segment between hog producers/farmers and pork packers. In the simulation analyses, the effects of hypothetical restrictions on the use of AMAs were evaluated for the entire vertically integrated chain, from producers to packers to consumers. The other analyses focus, in particular, on hog producers and pork packers. The analyses rely primarily on the data reported in the hog producers' survey, the pork packers' survey, the packer purchasing side of the individual transactions data, and the individual packers' P&L data. To supplement the analyses conducted using the survey and transactions data and to address some of the specific study questions, secondary and publicly available data were used also.

Primary conclusions for this final report, as they relate to the hog and pork industries, are as follows:

- **AMAs are an integral part of hog producers' selling practices and pork packers' procurement practices.** There are significant regional differences in the observed patterns of use of AMAs: a stronger reliance on cash/spot markets and marketing contracts is apparent in the Midwest and a stronger reliance on production contracts and packer ownership of hogs is apparent in the East. The pattern of future use of AMAs is not expected to change dramatically; hence, we do not expect that hog industry industrialization will emulate the industrialization of the poultry sector.
- **Based on individual transactions data, there are substantial differences in daily hog prices paid by packers on a carcass weight basis.** On average, the price dispersion is about 40% of the average value of the transaction prices each day. One part of such strong price dispersion can be explained by factors such as region, quality, or plant size. However, even after controlling for these factors, the remaining differences must be due to organizational issues related to supply chain management in the pork processing sector.
- **Results indicate that, on average, plants that use a combination of marketing arrangements pay lower prices for their hogs relative to plants that use the cash/spot market only.** In addition, comparing the magnitudes of the portfolio effects to the magnitudes of the individual marketing arrangement effects shows that individual marketing arrangements have minimal additional impact on the average price after accounting for the portfolio effect. That is, the portfolio system categorical variables capture almost the entire effect on lowering the average price.
- **Of particular interest for this study is the effect of both contract and packer-owned hog supplies on spot market prices; as anticipated, these effects are negative and indicate that an increase in either contract or packer-owned hog sales decreases the**

spot price for hogs. Specifically, the estimated elasticities of industry derived demand indicate

- a 1% increase in contract hog quantities causes the spot market price to decrease by 0.88%, and
- a 1% increase in packer-owned hog quantities causes the spot market price to decrease by 0.28%.

A higher quantity of either contract or packer-owned hogs available for sale lowers the prices of contract or packer-owned hogs and induces packers to purchase more of the now relatively less expensive hogs and purchase fewer hogs sold on the spot market.

- **Based on tests of market power for the pork industry, we found a statistically significant presence of market power in live hog procurement.** However, the results regarding the significance of AMA use for procurement of live hogs in explaining the sources of that market power are inconclusive. Whereas the model based on farm–wholesale price spread data shows that a higher proportion of AMA use leads to increased market power, the model estimated with company-level individual transactions data indicates that AMA use may not be a source of market power in pork packing.
- **Estimated total and average cost functions indicate that economies of scale diminish as the pork packing firm size increases.** The estimates indicate that the scale economies are exhausted well within the sample output range such that the biggest plants already exhibit negative returns to scale. That is, they operate on the upward-sloping portions of their average cost curves. The observed patterns of procurement portfolio choices by packers also indicate that certain combinations of marketing arrangements may reduce costs and/or increase economies of scale. In particular, relative to using spot market procurements alone, all other combinations of marketing arrangements improve the efficient scale of production.
- **Based on the observation that packers use marketing arrangements in clusters (portfolios), we hypothesized that marketing arrangements may be complementary to each other in the sense that implementing one procurement practice may increase the marginal return of the other practice; however, the analyses of the complementarity of marketing arrangements produced inconclusive results.** Simpler tests based on the correlation/association approach indicate that marketing

contracts are in fact complementary to production contracts and/or packer owned arrangements. Also, the portfolio coefficients in the performance equations based on either the earnings before insurance and taxes (EBIT) or the gross margin show that all marketing arrangement portfolios improve plant performance relative to simple spot market purchases. However, the coefficient associated with the portfolio of three marketing arrangements is smaller than the coefficient associated with portfolios of two marketing arrangements, thus violating the complementarity requirement. More conclusive formal tests were not feasible given data limitations.

- **To analyze quality differences in live market hogs across alternative procurement methods (AMAs), we tested whether various quality attributes used by the industry are significantly different across AMAs and found that different AMAs are associated with different levels of quality of hogs.** Even though the rankings are not unique, we found that marketing contracts (especially other purchase arrangements and other market formula purchases) are consistently associated with higher quality hogs than negotiated (spot market) purchases.
- **An examination of the relationship between the proportion of AMAs used to procure live hogs and the quality of resulting pork products indicates that a higher proportion of AMA use is associated with higher quality pork products.** We measured pork product quality using Hicks' composite commodity index and hypothesized that a higher percentage share of the AMAs (essentially marketing contracts and packer-owned hogs) should produce higher quality pork products. The correlation coefficient showed that these two series are positively correlated, thus confirming our hypothesis.
- **An analysis of risk associated with different marketing arrangements shows that different types of marketing arrangements exhibit different price volatilities as measured by the variance of prices.** Therefore, hog producers selling hogs using different types of marketing arrangements experience different levels of risk. From the hog producers' point of view, the ordering of marketing arrangements in decreasing order of risk is as follows: (1) spot/cash market sales; (2) marketing contracts in which the pricing formula is based on spot market prices; (3) marketing arrangements in which the pricing formula is

based on some futures or options price; (4) other purchase arrangements containing ledgers, windows, and other pricing mechanisms, which may serve as a cushion against price volatility; and (5) production contracts.

- **In analyzing the importance of hog producers' risk aversion for contract choice, we found that hog producers who use production contracts are more risk averse than producers who use cash/marketing arrangements.** The difference in risk exposure between contract producers and independent farmers is substantial because production contracts eliminate all but 6% of total income volatility. Therefore, the utility losses associated with forcing producers to market their hogs through channels different from their risk-aversion-preferred marketing arrangement choice are substantial.
- **In analyzing the economic effects of hypothetical restrictions on the use of AMAs in the hog and pork industries, we found that hog producers would lose because of the offsetting effects of hogs diverted from AMAs to the spot market, consumers would lose as wholesale and retail pork prices rise, and packers would gain in the short run but neither gain nor lose in the long run.** The results applied to three different simulations: (1) 25% reduction in both contract- and packer-owned hogs, (2) increase the spot/cash market share to 25%, and (3) complete ban of packer-owned hogs. The reason that producers and consumers lose in all three simulation scenarios is because of efficiency losses from reducing the proportion of hogs sold through contracts and/or packer owned channels. Although a reduction in AMAs leads to an improvement for hog producers through a reduction in the degree of market power, the loss in cost efficiencies offsets the gains from reduced market power. In all instances, the price spread between farm and wholesale prices would be expected to increase because of the net increase in the costs of processing. Moreover, wholesale, and hence retail, prices would increase, causing pork to become more expensive for consumers.

Decisions regarding methodologies, assumptions, and data sources used for the study had to be made in a short period of time. The analyses presented in this volume are based on the best available data, using methodologies developed to address the study requirements under the time constraints of the study.

However, we faced many challenges in resolving inconsistencies within each source and across sources of data under the tight schedule dictated by the study. For example, the plant-level comparison of procurement methods for market hogs between the individual transactions data and survey data reveals substantial differences in some cases. Also, the differences between carcass weight prices and liveweight prices indicate an unreasonably high implicit average yield ratio, which we were unable to resolve. Throughout the report, secondary data, as available, were used to supplement primary data to conduct the analyses.

1 Introduction and Background

AMAs include all possible alternatives to the use of cash or spot markets for conducting transactions.

As part of the congressionally mandated Livestock and Meat Marketing Study, this volume of the final report presents the results of analyses of the effects of AMAs in the hog and pork industries. The types of questions posed by the Livestock and Meat Marketing Study include the following: What types of marketing arrangements are used? What is the extent of their use? Why do firms enter into the various arrangements? What are the terms and characteristics of these arrangements? What are the effects and implications of the arrangements on participants and on the livestock and meat marketing system?

The overall study comprises five parts based on the performance work statement in the contract with GIPSA. An interim report released in August 2005 addressed the first two parts, Parts A and B, of the study (Muth et al., 2005). It described marketing arrangements used in the livestock and meat industries and defined key terminology.[1] Results presented in the interim report were preliminary because they were based on assessments of the livestock and meat industries using published data, review of the relevant literature, and industry interviews.

This final report describes the results of quantitative analyses addressing Parts C, D, and E of the study as follows:

- Part C. Determine extent of use, analyze price differences, and analyze short-run market price effects of AMAs.

[1] A glossary of terms used in the study is included as a separate document.

The interim report released in August 2005 addressed the first two parts of the study. This final report focuses on the final three parts of the study (Parts C, D, and E).

- Part D. Measure and compare costs and benefits associated with spot and AMAs.
- Part E. Analyze the implications of AMAs for the livestock and meat marketing system.

The analyses presented in this volume address these final three parts of the study using information from industry interviews,[2] data from the industry surveys (described in Volume 2), transactions data and profit and loss statements from packers and processors, and a variety of publicly available data. Analyses conducted for the Livestock and Meat Marketing Study are limited to economic factors associated with spot and AMAs and do not analyze policy options or make policy recommendations.

1.1 OVERVIEW OF THE HOG AND PORK INDUSTRIES

In this section, we describe the stages of hog production and location of operations as background information for analyses described in later sections of this volume.[3]

1.1.1 Stages of Pork Production

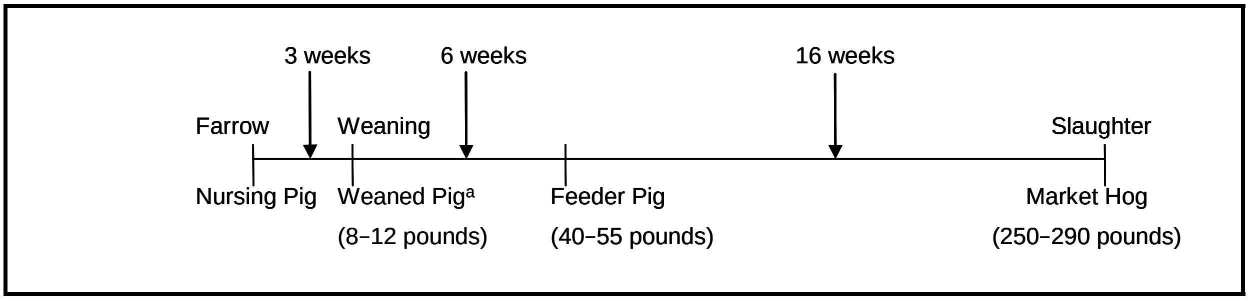
Traditionally, hogs were raised in farrow-to-finish operations on small diversified farms where hogs provided price risk protection for grain production. Starting in the 1950s, many farmers adopted new technologies that allowed them to grow and specialize in feed grain production. Some farmers discontinued hog production because the opportunity cost of time and land increased, and risk protection for feed grains was supplemented by income and price supports (Spinelli, 1991). Hogs are now commonly produced by specialized operations that separate production facilities for each phase of production and purchase or process their feed rations.

The production phases are categorized into three segments: farrow-to-wean, wean-to-feeder, and feeder-to-finish. The output from one production segment is generally the input into the next segment; however, the lines that separate each segment are less pronounced in actual production. Figure 1-1 illustrates a typical timeline for hog production.

[2] A description of the process for conducting the interviews and the complete findings from the interviews is provided in the interim report (Muth et al., 2005).

[3] A more complete overview of the hog and pork industries is provided in the interim report (Muth et al., 2005).

Figure 1-1. Hog Production Timeline
Capital-intensive production has solidified hog production methods into relatively precise segments.



[a] Also known as nursery pig or isowean.

During the **farrow-to-wean** phase, hog producers house parent stock sows that are bred by natural or artificial insemination for the production of nursing pigs. These pigs are weaned from the sow at 2 to 3 weeks of age, at which time they weigh between 8 and 12 pounds each.

Following the farrow-to-wean stage, hogs enter the **wean-to-feeder** production stage. This transition occurs in several different ways: weaner pigs might remain at the same physical location as the sow, weaner pigs might be shipped to a separate location, or younger aged isoweans might be shipped to a separate (isolated) nursery facility. Whichever method is used, the pigs are fed for approximately 6 weeks until they weigh between 40 and 55 pounds. The hogs are then ready to enter the final feeder phase of production.

In the **feeder-to-finish** segment, feeder pigs are fed for approximately 16 weeks until they reach a market weight of 250 to 290 pounds. Operations that retain weaned hogs up to the feeder stage might continue to feed those animals to market weight (farrow-to-finish operations), or they might choose to sell the hogs rather than feed them (farrow-to-feeder operations). Hogs from nursery operations are transferred into a separate finishing operation. Some growers specialize in the final two production stages and purchase weaner pigs to raise them to slaughter weight (wean-to-finish). However, given the vastly different level of care weaner pigs need relative to finishing hogs, this type of production is not as common.

Some packers only slaughter hogs and sell the carcasses to a separate processor or breaker; however, the majority of packers have their own fabrication facilities.

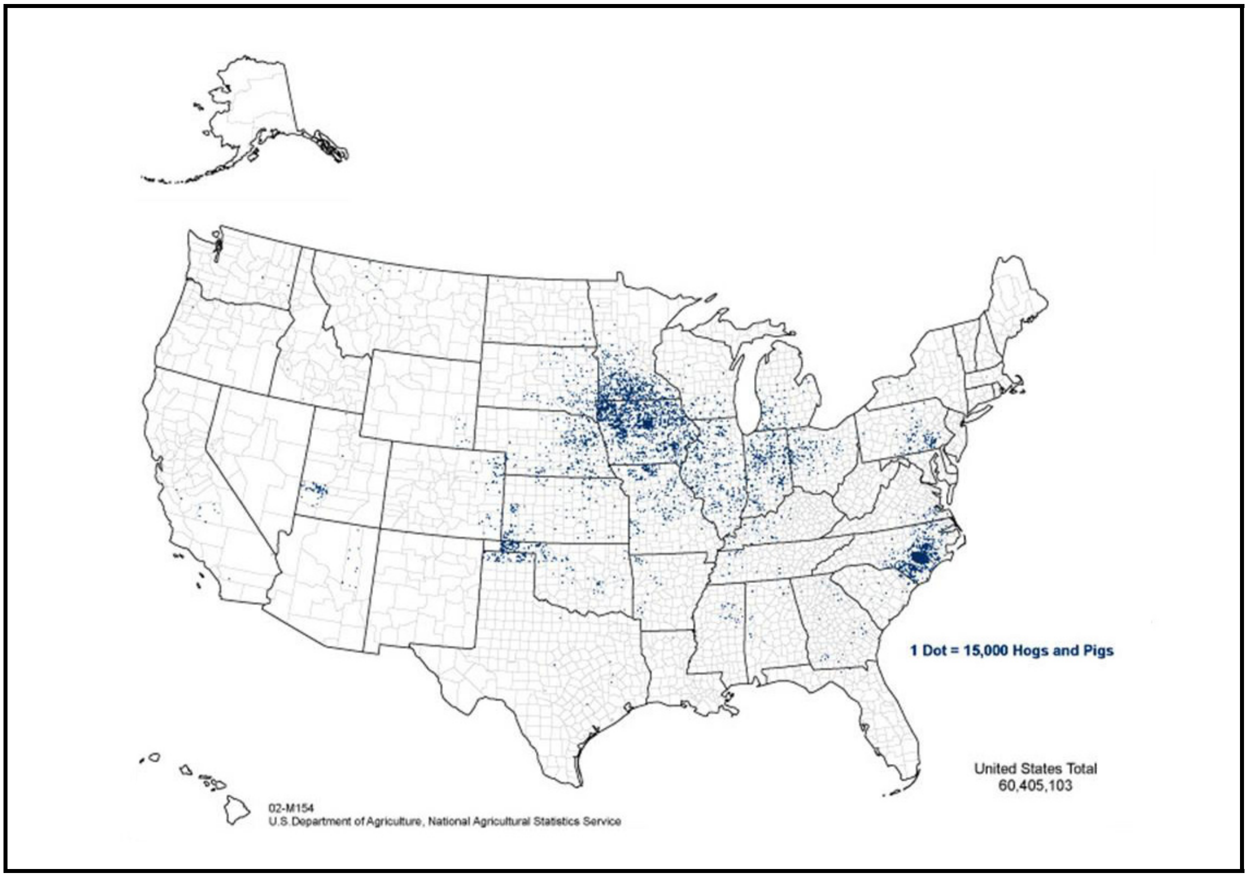
Regardless of the method used to raise the pigs, the finished market hogs are shipped to a slaughter facility (packer). As with all meat types, hog carcasses are inspected for wholesomeness by the U.S. Department of Agriculture (USDA)/Food Safety and Inspection Service (FSIS) or by a state government inspection system. However, unlike beef, pork is rarely quality graded by USDA/Agricultural Marketing Service (AMS). Instead, packers rely on other measures of quality, such as lean percentage, back fat, and loin eye depth. After the hogs have been slaughtered, the carcasses are chilled and then sent to the fabrication area of the plant where they are broken down into pork cuts. Some packers only slaughter hogs and sell the carcasses to a separate processor or breaker; however, the majority of packers have their own fabrication facilities. The largest cuts are primals consisting of groups of muscles from the same area of the carcass. These primals are further cut into subprimals and portion cuts. Fresh meat cuts are typically sold as boxed pork, which refers to similar cuts that are boxed together for shipping. Many of these meat cuts will still need to be further processed or repackaged by the buyer before they are ready for sale to consumers. Packers also package case-ready meats that are ready to be placed in the retail meat case.

1.1.2 Locations of Pork Operations

Hog production has been shifting over time from the Corn Belt States to other states such as North Carolina, Oklahoma, Utah, and Wyoming.

Hog production in the United States has historically been concentrated in the Corn Belt States. In 1990, Iowa, Illinois, Minnesota, Indiana, and Nebraska had the largest hog inventories in the country (USDA/NASS, 1994). As discussed above, hog production was traditionally part of diversified farming practices, and given that feed costs account for approximately 60% of the cost for producing market hogs (Lawrence, Kliebenstein, and Hayenga, 1998), hog producer operations were located close to feed supplies. However, by 1994, North Carolina had the second largest hog inventory in the country (USDA/NASS, 1998), thus indicating a shift in production locations. Between 1990 and 2003, the largest growth percentages in hog inventory were in Utah, Oklahoma, Wyoming, and North Carolina, respectively. Figure 1-2 maps the U.S. inventory of hogs in 2002. Many of the nontraditional hog-producing states now supply the Corn Belt States with feeder pigs. For example, in 2003 Iowa imported as many feeder hogs from Canada and other states as it produced locally

Figure 1-2. U.S. Inventory of Hogs and Pigs, 2002
Most of the hog production is conducted in the Corn Belt and the Southeast.



Source: U.S. Department of Agriculture, National Agricultural Statistics Service. 2004. "2002 Census of Agriculture." Washington, DC: USDA. <http://www.nass.usda.gov/research/atlas02/>.

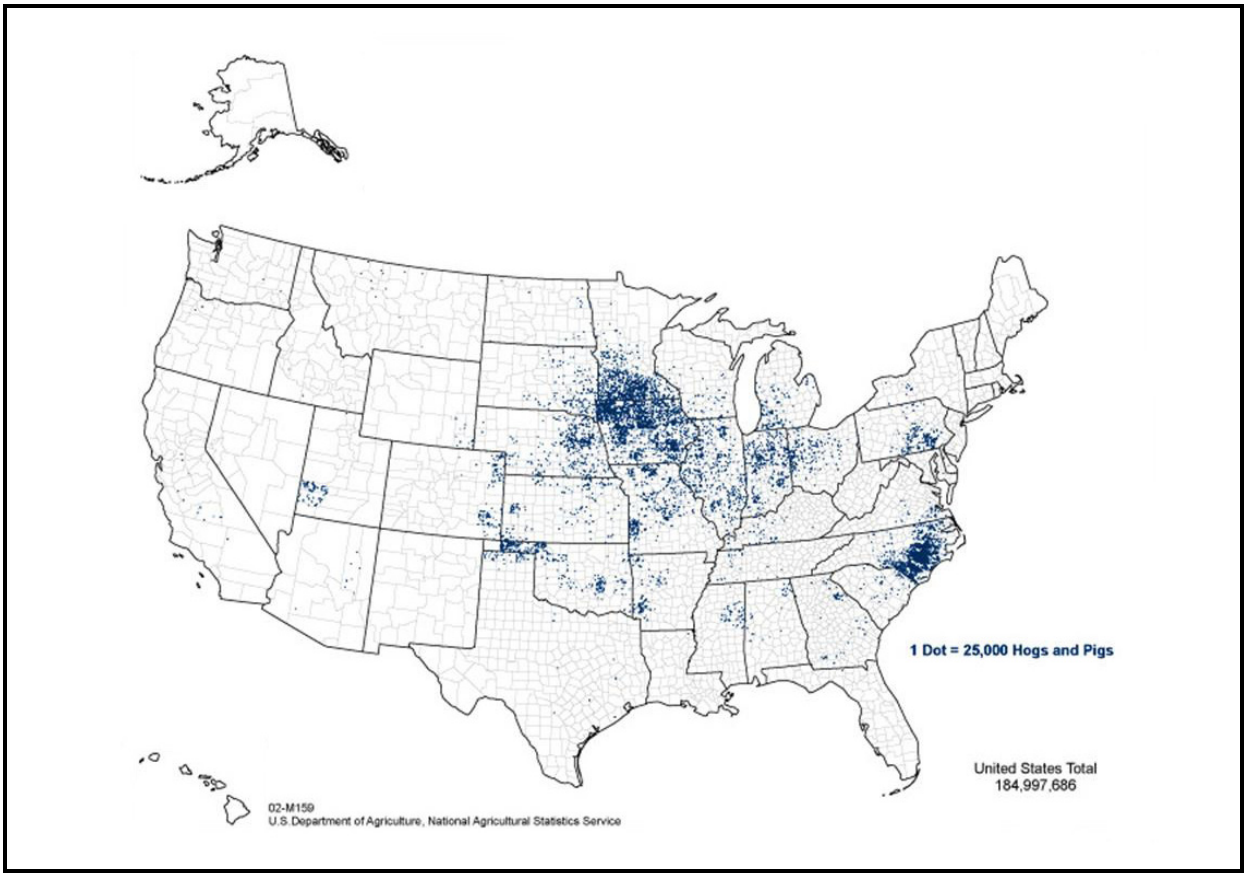
(Haley, 2004), suggesting that producers in Iowa are becoming more specialized in feeding operations.

Transporting intermediate-stage hogs to different geographical areas is a relatively new practice. Hog production has always been unique compared with other livestock species, in that breeding and finishing occur in the same area. Figure 1-3 shows that in 2002 the regions of the Southeast and the Corn Belt that dominate production were also the regions where most hogs are sold.

The largest hog packers are located close to hog production facilities.

As the location of hog inventories has changed, so has the location of slaughter facilities (Figure 1-4). In 1990, almost 60% of U.S. slaughter capacity was located in Iowa and surrounding states. By 2003, North Carolina had become the second largest state in slaughter capacity. Large increases in hog inventories for nontraditional hog-producing states (e.g.,

Figure 1-3. Number of Hogs and Pigs Sold, 2002
All phases of hog production are conducted in the same geographical locations.



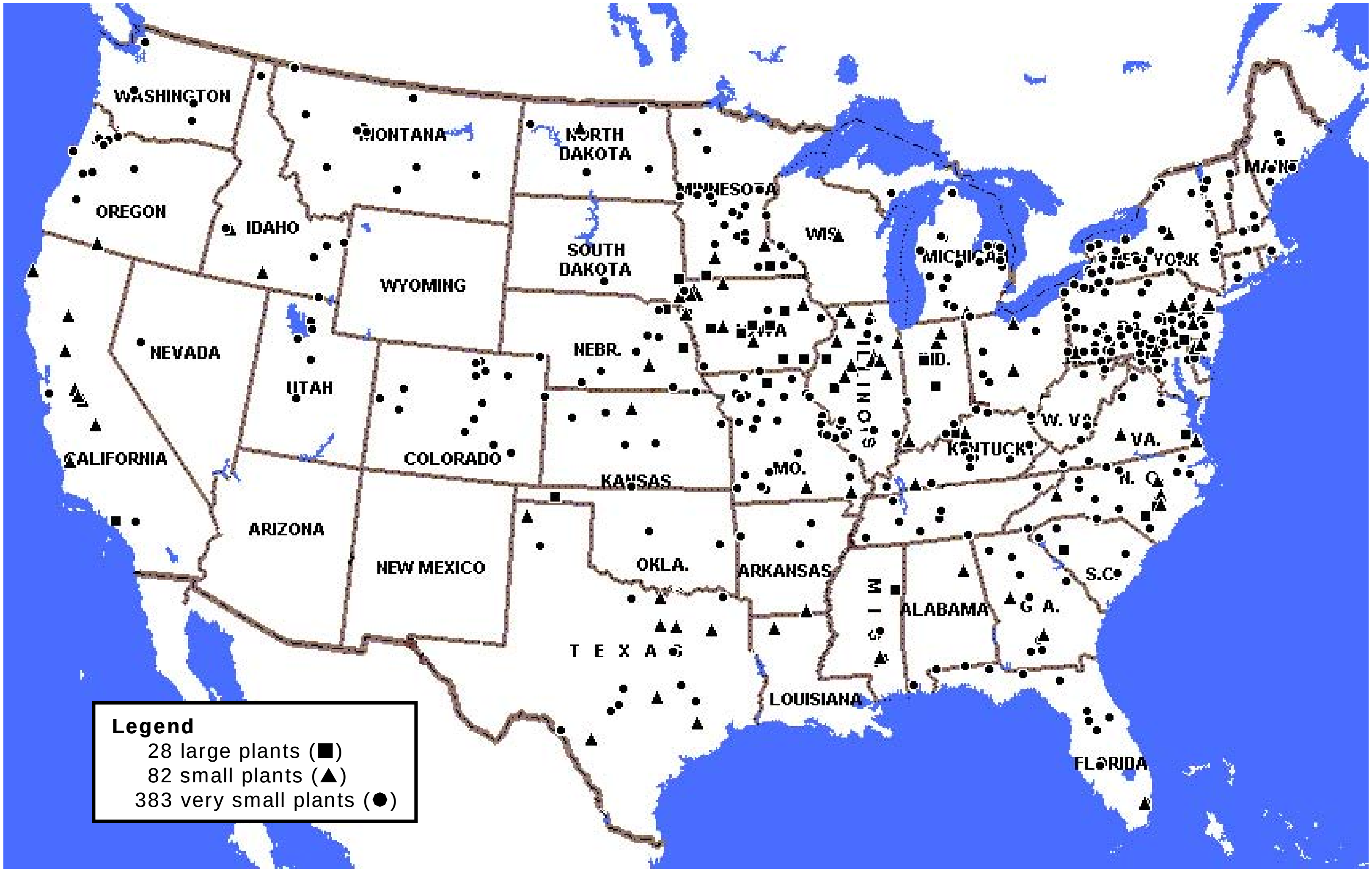
Source: U.S. Department of Agriculture, National Agricultural Statistics Service. 2004. "2002 Census of Agriculture." Washington, DC: USDA. <http://www.nass.usda.gov/research/atlas02/>.

Oklahoma and North Carolina) directly coincide with the opening of large slaughter facilities in those states. Comparing Figures 1-3 and 1-4 shows that the largest packers continue to be located close to production facilities.

1.1.3 Trends in Pork Operations

The total U.S. inventory of hogs and pigs (Figure 1-5) has remained relatively stable since 1990; however, there has been significant variation within the individual stages of production. The number of breeding hogs decreased 17% from 1991 to 2005. During the same period, the number of market hogs increased by more than 9%.

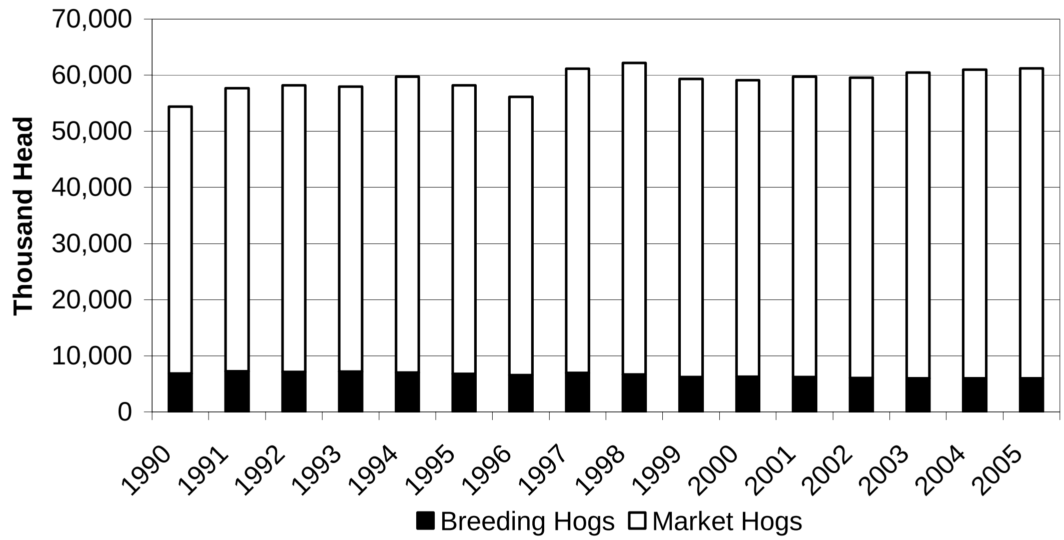
Figure 1-4. Location of Federally Inspected Plants that Slaughter Barrows and Gilts[a]



[a] Plants that slaughtered at least 50 head of barrows and gilts in FY2004 (October 1, 2003 through September 30, 2004) are included. Of 493 plants, 28 are classified by FSIS as large, with 500 or more employees; 82 are classified as small, with 10 to 499 employees; and 383 are classified as very small, with fewer than 10 employees or less than $2.5 million in annual sales. Plants in Alaska (2) and Hawaii (5) are not shown.

Source: RTI International. 2005. Enhanced Facilities Database. Prepared for the U.S. Department of Agriculture, Food Safety and Inspection Service. Research Triangle Park, NC: RTI.

Figure 1-5. U.S. Inventory of Hogs and Pigs, December 1, 1990–2005
Hog and pig inventory categories include breeding hogs (all hogs kept for breeding purposes) and market hogs (all hogs from those less than 60 pounds to those greater than 180 pounds that are intended for sale as market hogs).



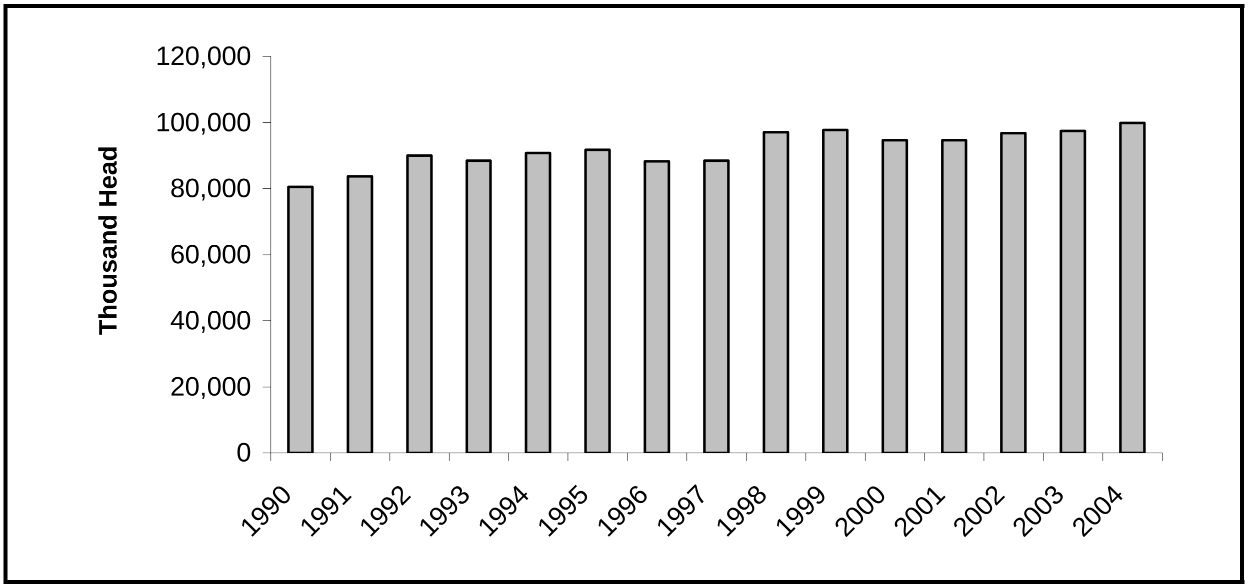
Source: U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.>

The net effect of the changing domestic herd and Canadian imports is a steadily growing number of market hogs, barrows, and gilts slaughtered by U.S. packers.

To reconcile the difference between the decreasing size of the breeding herd and the increasing number of market hogs, a comparison can be made between the number of pigs born per litter and the number of pigs per breeding animal. The number of pigs per breeding animal per year grew by 57% between 1979 and 2001, with 29% of that increase attributed to the increase in the average litter size. The remaining 71% is attributed to the increase in the number of litters per sow per year (USDA/NASS, 2002). Collectively, this shows that the efficiency of the U.S. breeding herd is improving in terms of delivering more pigs from a smaller breeding herd. The difference between the decreasing breeding herd and the increasing number of market hogs is also partially offset by imported feeder hogs. Canada is the primary supplier of live hogs to the United States, providing 99.99% of the 7 million plus hogs imported in 2003 (Haley, 2004). More than 65% of those animals were imported as 10- to 40-pound feeder hogs that were fed to slaughter weight in the United States.

The net effect of the changing domestic herd and Canadian imports is a steadily growing number of market hogs (barrows and gilts) slaughtered by U.S. packers (Figure 1-6). Market hogs constitute over 96% of the hogs slaughtered in the country (USDA/GIPSA, 2002). The average annual growth in slaughter volume was approximately 2% between 1990 and 2004.

Figure 1-6. U.S. Commercial Barrow and Gilt Slaughter, 1990–2004
Commercial barrow and gilt slaughter includes animals slaughtered at federally inspected and nonfederally inspected plants but does not include animals slaughtered on the farm.

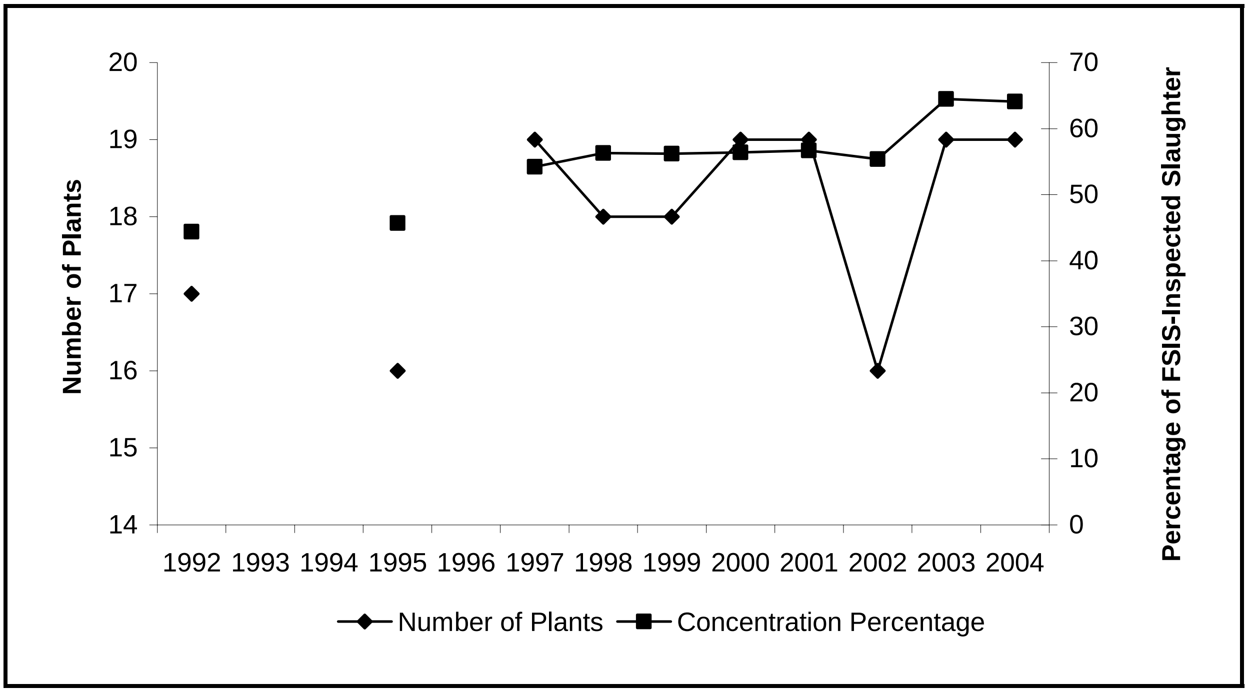


Source: U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.>

Packers were able to produce more pork per pig slaughtered, as the average market hog's liveweight increased by 17 pounds and carcass weight increased 20 pounds during the same period. Availability of hogs and carcass weight are two of the factors that contribute to individual packer efficiency. Packers have increasingly built larger facilities that operate closer to capacity to decrease per-unit costs of production (Ward, 2003). This shift in operations was facilitated by the decrease in seasonal fluctuations of hog production. Previously, packers maintained excess capacity for most of the year to accommodate large slaughter levels during the last quarter of the year (Haley, 2004). Subsequently, fewer packing facilities are currently operating. In fiscal year 2002, 558 federally inspected plants slaughtered at least 50 market hogs. However, as indicated in the CR4, the four largest packers slaughtered over 50% of the hogs under federal inspection since 1997 (Figure 1-7). The total number of plants operated by these companies has varied since 1992.

Figure 1-7. U.S. Hog Packer Four-Firm Concentration Ratio (CR4), Selected Years, 1992–2004

The CR4s show the percentage of all hogs slaughtered at plants owned by the four largest firms during the respective year. The total number of plants operated by those firms is also included. Percentages are based on total federally inspected slaughter numbers.

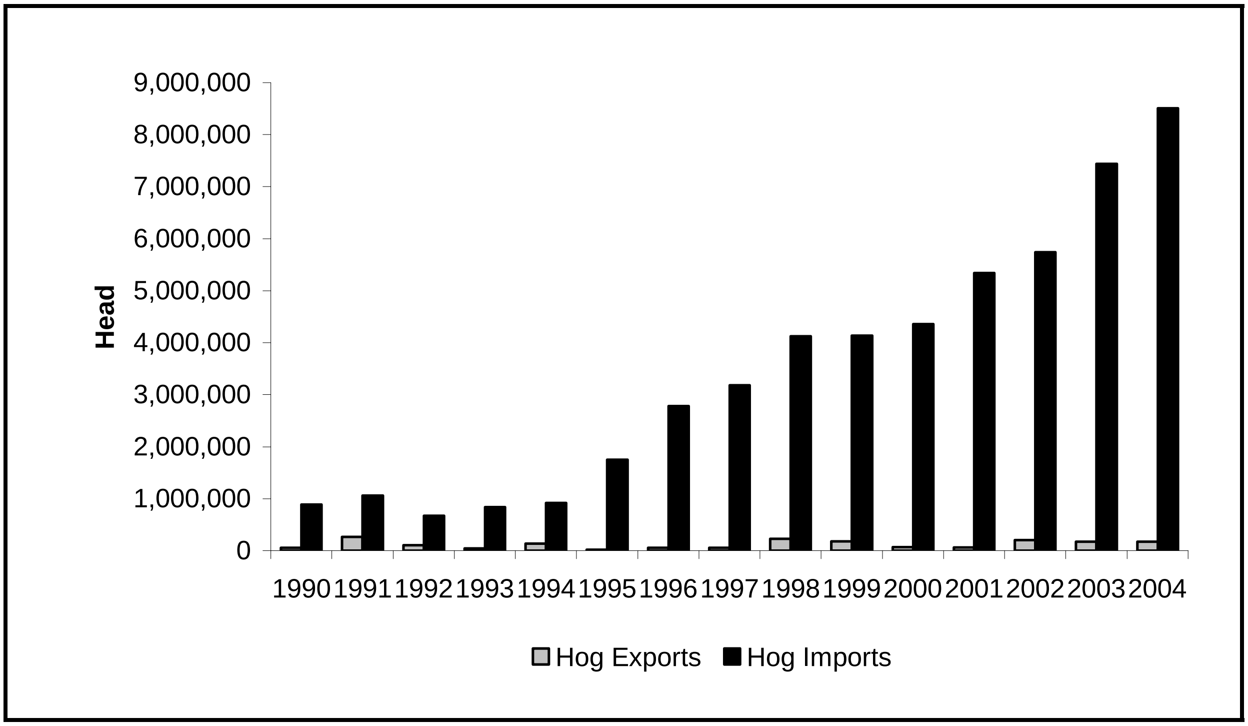


Source: U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration. 2004. *Packers and Stockyards Statistical Report*. SR-06-1. Washington, DC: GIPSA.

1.1.4 Imports and Exports of Hogs and Pork

The United States is a net importer of live hogs (Figure 1-8). As discussed earlier, virtually all the live hogs imported into the United States are from Canada. The total number of hogs imported increased dramatically since 1990, while the type of hogs imported changed concurrently. In 1990, 77% of the Canadian hogs were slaughter hogs and 23% were feeder pigs. By 2003, the numbers switched: 33% of imported hogs were slaughter hogs and 67% were feeder pigs. Approximately 95% of the feeder pigs are shipped to Midwest and Corn Belt States. Slaughter hog shipments are more dispersed, but the majority of shipments are destined for the Western States (Haley, 2004). Mexico consumes over 80% of U.S. live exports. From mid-1980 to the early 2000s, nearly two thirds of live exports

Figure 1-8. Total U.S. Hog Imports and Exports, 1990–2004
The United States is a net importer of live hogs. Live animal trade is typically restricted to North America.



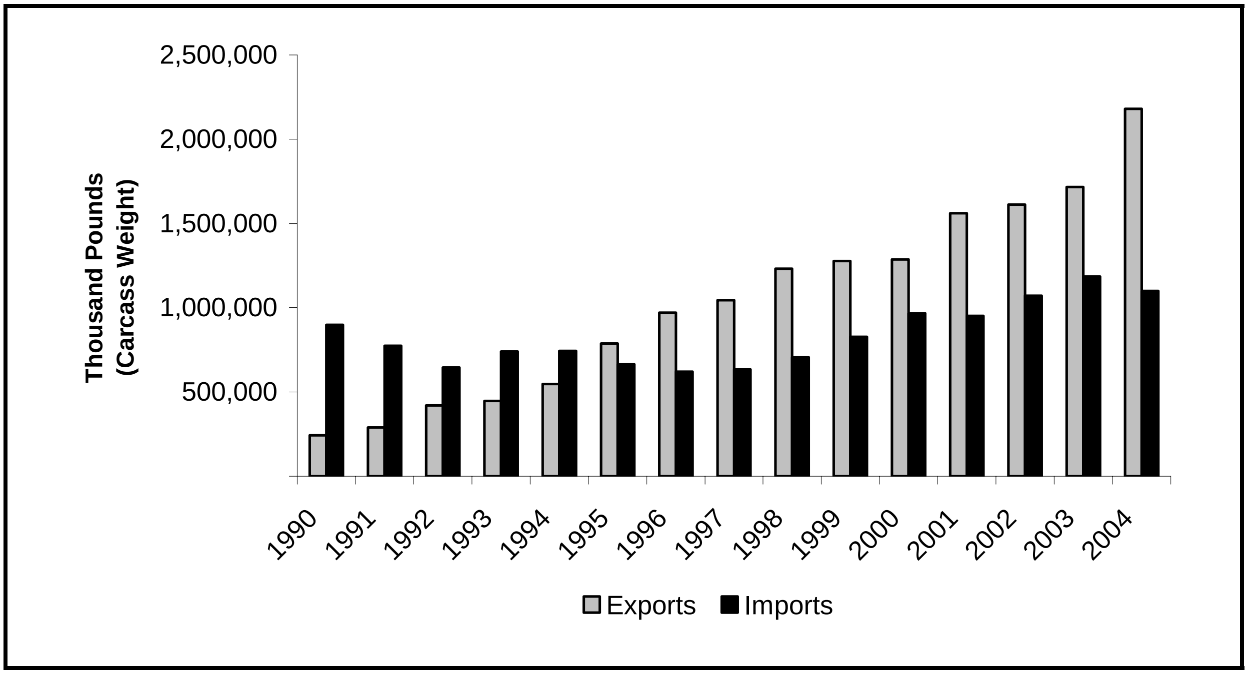
Source: U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.>

were slaughter hogs, and approximately one third were breeding animals (USDA/ERS, 2004).

The United States has recently become a net exporter of pork products (Figure 1-9). In addition, the United States is the third largest pork importer in the world. In 2003, pork imports were approximately 6% of U.S. pork consumption, and exports were approximately 9% of U.S. pork production (USDA/ERS, 2004). Over three quarters of the U.S. pork exports are sent to Japan, Mexico, and Canada. Japan, the world's largest pork importer, consumes 46% of U.S. pork exports (USDA/ERS, 2004). Canada and Denmark continue to be the primary suppliers of imported pork to the United States. Expansion in the Canadian hog industry and lower costs relative to Denmark have allowed Canada to become the dominant foreign supplier since 1985 (USDA/ERS, 2004).

Figure 1-9. Total U.S. Pork Imports and Exports, 1990–2004

The United States has become a net exporter of pork products. Canada, Denmark, and the Netherlands are the primary sources of imported pork. Japan, Mexico, and Canada are the primary destinations for exported U.S. pork.



Source: U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.>

1.2 OVERVIEW OF MARKETING ARRANGEMENTS IN THE HOG AND PORK INDUSTRIES

In this report, cash or spot market transactions refer to transactions that occur immediately or "on the spot." These include auction barn sales; video or electronic auction sales; sales through order buyers, dealers, and brokers; and direct trades. The terms "cash market" and "spot market" are used interchangeably. "AMAs" refer to all possible alternatives to the cash or spot market. These include arrangements such as forward contracts, marketing agreements, procurement or marketing contracts, packer owned, production contracts, custom feeding, and custom slaughter. For AMAs at the producer level, livestock may be owned by the individual(s) that owns the farm or facility, or they may be owned by a different party.

In addition to the type of procurement or sales method, other key dimensions that define each marketing arrangement are ownership method of the animal or product, pricing method, and valuation method for livestock. Pricing method is further defined by formula base, if formula pricing is used, and internal transfer pricing method, if the product is internally transferred within a single company.

Figure 1-10 illustrates the types of marketing arrangements used for sales of live pigs and hogs. The key dimensions of marketing arrangements at each stage include the **ownership method** for the animal or product while it is at an establishment (e.g., hogs owned by the producer or owner of the farm, hogs not owned by the producer, and packer-owned farms) and the **pricing method** used. If formula pricing is used, a **formula base price** must be specified. The **valuation method** for carcasses might be on a per-head basis, liveweight basis, carcass weight basis, or primal cuts basis. Carcass weight valuation might be based on a grid that offers premiums or discounts based on weight and carcass quality grade. If animals or products are shipped from one establishment to another owned by the same company, an **internal transfer pricing method** must be specified.

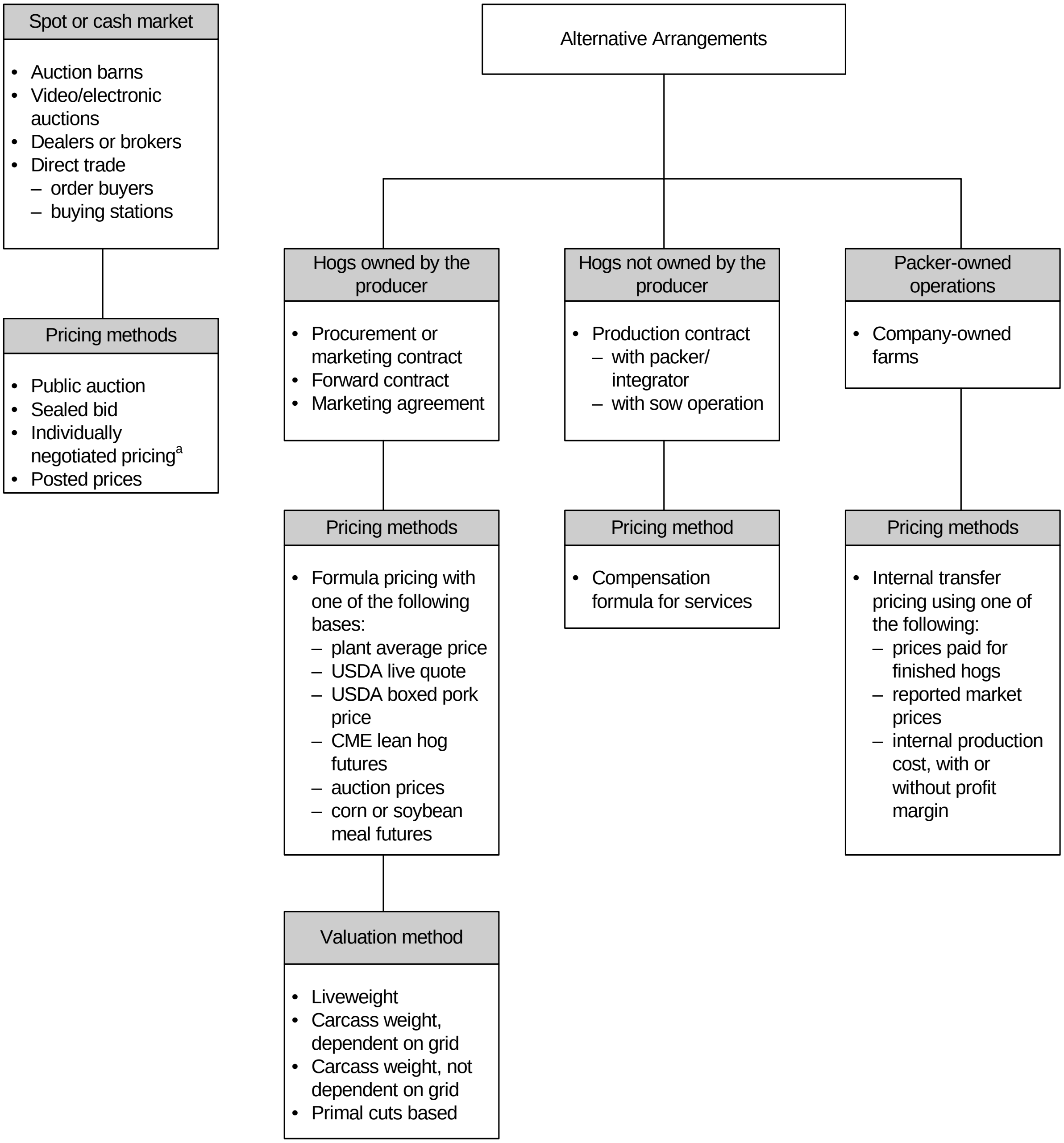
Production contracts and marketing contracts as used in the pork industry are unique types of marketing arrangements and warrant further description. **Production contracts** specify the division of production inputs supplied by the two parties, the quality and quantity of a particular output, and the type of the remuneration mechanism for the grower. The hogs are owned by the contractor (packer or integrator) who also assumes most of the price risk and some of the production risk. Because contractors control the volume of production and production practices, they tend to dictate the terms of contracts.

Marketing contracts refer to an agreement that establishes a price or pricing mechanism and an outlet for the product prior to harvest. Most management decisions remain with the growers because ownership is retained until harvest. Producers also assume all production risk but share price risk with a contractor. Forward contracting and price setting after delivery based on a predetermined formula that reflects quality grades and yields are examples of marketing contracts.

The types of buying and selling mechanisms vary by stage of the pork production system. Figure 1-11 illustrates the types of marketing arrangements used for sales or transfers of all types of meat products (including pork) by packers. Under AMAs, meat products might be sold by the packer or transferred to

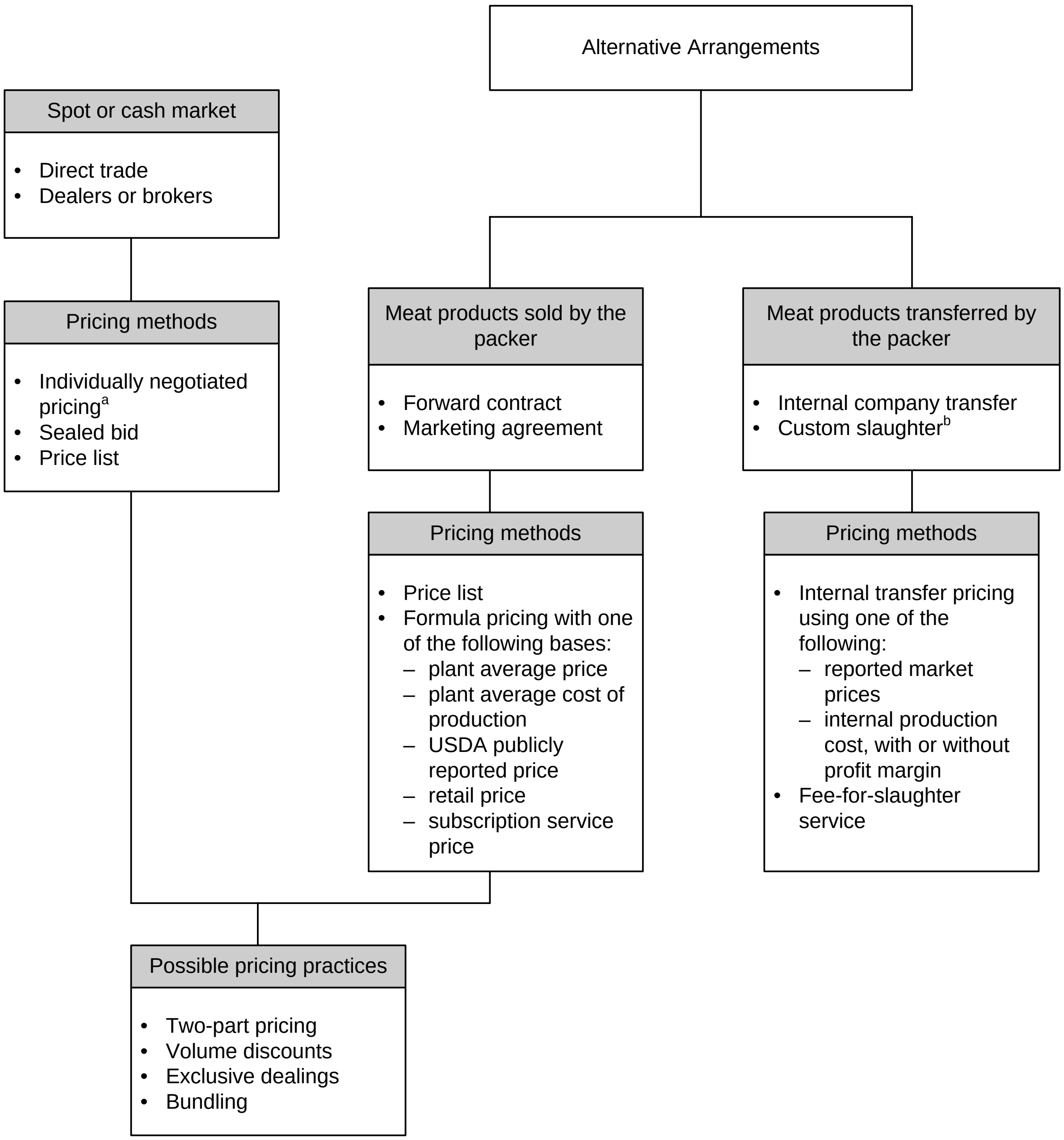
Figure 1-10. Marketing Arrangements for Sale or Transfer of Weaner, Feeder, and Finished Hogs by Pork Producers

Different types of pricing methods are associated with each type of marketing arrangement used in the industry.



[a] Individually negotiated pricing is often benchmarked against reported prices.

Figure 1-11. Marketing Arrangements for Sale or Transfer of Meat Products from Packers
Meat products are sold or transferred to processors, wholesalers, exporters, food service operators, or grocery retailers.



[a] Individually negotiated pricing is often benchmarked against reported prices.

[b] Custom slaughter may be coordinated by a cooperative for its producer-members.

another establishment owned by the same company or to the owner of the livestock if custom slaughtered. Spot or cash market sales of meat are primarily conducted via individual negotiations. Transactions may be for very large or very small volumes and may be for carcasses, single cuts, or a variety of cuts. Other pricing practices used for meat products might include two-part pricing, volume discounts, exclusive dealings, and bundling.

1.3 ORGANIZATION OF THE HOG AND PORK STUDY VOLUME

In the remaining sections of this volume, we present results of the study for the hog and pork industries. Section 2 provides results on volume differences, price differences, and market price effects associated with AMAs. Section 3 provides results on economies of scale, cost, and efficiency differences associated with AMAs. Section 4 provides results on quality differences and Section 5 provides results on risk shifting associated with AMAs. Section 6 provides results on the measurement of welfare affects associated with restricting AMAs by simulating hypothetical scenarios. Finally, Section 7 describes the implications of AMAs including the incentives associated with changing the use of AMAs and the expected effects of possible changes in use of AMAs over time.

Note that each section of this volume addresses the requirements of the study as defined in the performance work statement for the contract. Section 2 addresses Part C; Sections 3, 4, and 5 address Part D; and Sections 6 and 7 address Part E.

In addition to these sections, Appendix A provides summary data on hog prices from the transactions data, Appendix B provides technical details on a model of the hog and pork industries from the packer perspective used for conducting simulations of restrictions on AMAs, Appendix C describes the Agricultural Resource Management Survey (ARMS) data used in parts of the analyses, and Appendix D provides estimation details for factor demand equations used in the modeling efforts.

2 Volume Differences, Price Differences, and Short-Run Spot Market Price Effects Associated with Alternative Marketing Arrangements

In this section, we present results on volume differences associated with AMAs, price differences across AMAs, and effects of AMAs on cash market prices.

2.1 DATA SOURCES FOR THE ANALYSES

The analyses described in this section are based on data from three different sources: surveys of pork producers and packers, pork packers' individual transactions (purchase) data, and Mandatory Price Reports (MPR) data. We describe these data below.

2.1.1 Surveys of Pork Producers and Packers

The surveys of pork producers and packers contain data on quantities, but not prices. The responses reflect the producers' or packers' activities in a self-chosen 12-month period between January 2004 and December 2005. The number of respondents to the surveys is 229 pork producers and 88 pork packers. In this section, we focus only on the transactions in the producer–packer relationship; that is, we deal only with those producers in the survey who sell market hogs. Market hogs are procured by packers as the production input into their packing plants.[1] Among the survey respondents, 25 pork producers (Question 6.1.c) and 3 pork packers (Question 1.4) did not provide the total number of market hogs they sold or procured during the last year. As a result, the usable number of observations in the pork producers data set is 204 and 85 in the pork packer data set. When using the survey results, we report both the raw survey numbers and the weighted responses. The survey weights are constructed so that the total national quantities of market hogs in the survey match the National Pork Board checkoff system numbers for 2004.[2]

2.1.2 Packers' Individual Transactions (Purchase) Data

The packers' individual purchase transactions contain data on prices and quantities. The data set consists of 2,103,322 individual transactions (lots) of hogs and pigs from 30 different pork packing plants during the time period October 2002 through March 2005.[3] Packers were asked to report the total number of hogs per lot and the number of barrows and gilts, sows, and boars and stags. However, only the total number of hogs was available for some plants. Therefore, we prescreened the data excluding observations outside reasonable bounds for either liveweight or carcass weight. When the total liveweight of a transaction was available, we calculated the average liveweight per head and excluded observations below 220 pounds or greater than 320 pounds. In cases where only carcass weights were available, we calculated the average carcass weight per head and eliminated observations below 150 pounds or greater than 220 pounds. In addition, we also excluded all transactions with five or fewer market hogs. After applying these data preparation steps, the number of transactions was 1,757,286.

Each transaction in the data included the base price (average base price paid for the lot), price adjustment (average merit-based adjustments, such as premiums and discounts), and pricing units. For transactions in which adjustments were reported, the net prices were calculated by summing the base

[1] Summaries of other survey results are presented in Volume 2, Section 6: Survey Results: Livestock Producers and Feeders and Volume 2, Section 7: Survey Results: Meat Packers.

[2] For details on constructing the survey weights, see Volume 2 of this report.

[3] For the exact instructions/protocol for data collection for pork packers, see Volume 2, Appendix D.

price and adjustment. The pricing units variable indicates whether prices were reported on the basis of liveweight or carcass weight. Some plants use both pricing units and some only use one type. For analysis purposes, we converted all liveweight prices to a carcass weight basis using the carcass weight to liveweight ratio (percentage yield) for that transaction. When liveweights or carcass weights were missing, we were unable to calculate yield; therefore, that transaction was dropped.[4] Similar to prescreening for nonmarket hogs, we screened transactions based on price. Observations with a price per hundred weight less than $20 or greater than $100 were dropped. This rule approximately corresponds to eliminating observations outside the upper and lower 1 percentile of the price distribution.[5] After this additional data preparation, we had 1,677,227 transactions from 29 processing plants owned by 15 different companies.

The implemented data preparation procedures caused a considerably smaller loss of information in terms of the actual number of market hogs transacted then appears to be the case based on the eliminated number of transactions (lots). The data preparation procedures eliminated 20.3% of all transactions (lots) but only 6.7% of the transacted market hogs. However, even the prepared data set still suffers from considerable deficiencies, whose origins are very difficult to determine. A couple of problems are worth mentioning. First, comparing the individual transactions data with survey data for a plant-level comparison of procurement methods for market hogs reveals nontrivial differences. For example, the percentage of reported cash/spot market purchases that a plant reported in the survey is sometimes more than 50 percentage points different than that indicated in the same plant’s transactions data. Second, the differences between carcass weight prices and liveweight prices indicate an unreasonably high implicit average yield ratio, for which we do not have a very good explanation. Both of these problems are carefully discussed and elaborated in the subsequent sections.

[4] For this reason, we were not able to use observations for one entire plant (they reported only liveweights). This plant was the smallest one in terms of the total number of market hogs purchased during the sample period.

[5] The distribution of carcass prices shows that the first percentile is $28.64 and the 99th percentile is $104.95 per hundred pounds.

2.1.3 Mandatory Price Reports (MPR) Data

The USDA/AMS Mandatory Price Reports[6] data records the transactions of National Daily Direct Hog Prior Day—Slaughtered Swine through the following categories of marketing arrangements (MAs):

- Negotiated Purchases (MA1): Cash or spot market purchase of hogs by a packer from a producer when there is an agreement on base price and a delivery day not more than 14 days after the date on which the livestock are committed to the packer.
- Other Market Formula Purchases (MA2): Purchase of hogs by a packer in which the pricing mechanism is a formula price based on any market other than the market for hogs, pork, or pork product. This includes formula purchases where the price formula is based on one or more futures and options contracts.
- Swine or Pork Market Formula Purchases (MA3): Purchase of hogs by a packer in which the pricing mechanism is a formula price based on a market for hogs, pork, or a pork product, other than any formula purchase with floor, window, or ceiling price, or a futures options contract for hogs, pork, or pork product.
- Other Purchase Arrangements (MA4): Purchase of hogs by a packer that is not a negotiated purchase, hogs or pork market formula purchase, or other market formula purchase and does not involve packer-owned swine. This would include long-term contract agreements; fixed price contracts; cost of production formulas; and formula purchases with a •oor, window, or ceiling price.
- Packer Owned (MA5): Hogs that a packer, including a subsidiary or affiliate of the packer, owns for at least 14 days immediately before slaughter.
- Packer Sold (MA6): Hogs that are owned by a packer, including a subsidiary or affiliate of the packer, for more than 14 days immediately before sale for slaughter and sold for slaughter to another packer.

In this section, we use the MPR data primarily as a reference point. To the extent that the individual transactions data correspond closely to the MPR data, they can be used with reasonable confidence. In other sections of this report, the MPR

[6] MPR is available at http://mpr.datamart.ams.usda.gov.

data have been used as the primary data source for various analyses.

2.1.4 Market Hog Volume Data

Before conducting analyses, we compared our data with other publicly available sources at the national and regional levels. We divided the national hog market into three regional markets: Eastern market, Midwestern market, and Other. Each region is defined as follows:

- East: North Carolina, South Carolina, Georgia, Virginia, Pennsylvania, Maryland
- Midwest: Illinois, Indiana, Iowa, Kansas, Kentucky, Minnesota, Missouri, Nebraska, Oklahoma, South Dakota, Wisconsin, Tennessee, Ohio
- Other: all other states

Tables 2-1a through 2-1e compare the number of market hogs produced or purchased in different regions across different data sources. Tables 2-1a and 2-1b present summaries of data from the pork producer and packer surveys. We report both the raw numbers and weighted sums. Table 2-1c summarizes market hog purchases from the pork packers' individual transactions data. The numbers reflect transactions from October 2002 through March 2005. For comparison purposes, we also extracted the data for calendar year 2004. Transactions data were only requested from large packers. The regional distribution of these plants reflects the geographical dispersion of the hog industry, with 7 plants in the Eastern region, 19 plants in the Midwest region, and 3 plants in other states. As Table 2-1c shows, the final data set consists of close to 1.7 million individual transactions (records); 655,000 of these occurred in 2004.

Data in Tables 2-1a through c are compared with the data available from two public sources. Table 2-1d summarizes market hog sales in 2004 from the National Pork Board Checkoff System, and Table 2-1e provides the number of hogs slaughtered commercially in 2004 reported in Agricultural Statistics (USDA, 2005). Because the survey weights are constructed to match the National Pork Board checkoff numbers, both producers' and packers' total quantities of market hogs match the checkoff numbers exactly, and are very close to the USDA numbers. The regional distributions are also

Table 2-1a. Market Hogs by Region: Pork Producers' Survey Data (Based on Q6.1.c[a])

Region	Number of Producers	Raw Number: Number of Market Hogs	Raw Number: Percentage	Weighted Sum: Number of Market Hogs	Weighted Sum: Percentage
East	16	489,222	13.9%	18,719,156	18.6%
Midwest	175	2,791,146	79.5%	77,595,023	77.0%
Other	13	231,283	6.6%	4,477,447	4.4%
Total	204[b]	3,511,651	100.0%	100,791,626	100.0%

[a] Q6.1.c: How many market hogs did your operation sell or ship during the past year?
[b] Of the 229 pork producers in the survey data set, 25 did not reply to Q6.1.c.

Table 2-1b. Market Hogs by Region: Pork Packers' Survey Data (Based on Q1.4[a])

Region	Number of Producers	Raw Number: Number of Market Hogs	Raw Number: Percentage	Weighted Sum: Number of Market Hogs	Weighted Sum: Percentage
East	26	14,819,608	19.5%	18,719,156	18.6%
Midwest	30	58,297,443	76.8%	74,387,321	73.8%
Other	29	2,804,179	3.7%	7,685,149	7.6%
Total	85[b]	75,921,230	100.0%	100,791,626	100.0%

[a] Q1.4: How many market hogs (barrows and gilts) were procured by your plant during the past year?
[b] Of the 88 pork packers in the survey data set, 3 packers did not reply to Q1.4.

Table 2-1c. Market Hogs by Region: Pork Packers' Transactions (Purchase) Data: October 2002–March 2005 and 2004 Only

Region	October 2002–March 2005: Number of Records	October 2002–March 2005: Number of Market Hogs	October 2002–March 2005: Percentage	2004 Only: Number of Records	2004 Only: Number of Market Hogs	2004 Only: Percentage
East	D	D		D	D	
Midwest	1,414,754	145,469,746	76.8%	544,231	57,653,358	75.7%
Other	D	D		D	D	
Total	1,677,227	189,481,919	100.0%	655,153	76,115,709	100.0%

D = Results suppressed.

Table 2-1d. Market Hogs by Region: National Pork Board Checkoff System, 2004

Region	Number of States	Number of Hogs	Percentage
East	6	18,719,156	18.6%
Midwest	13	75,090,931	74.5%
Other	31	6,981,539	6.9%
Total	50	100,791,626	100.0%

Source: http://www.pork.org.

Table 2-1e. Market Hogs by Region: Number Slaughtered Commercially, 2004

Region	Number of States	Number of Hogs Slaughtered	Percentage
East	5	17,751,900	17.61%
Midwest	13	79,121,000	78.49%
Other	26	3,932,200	3.90%
Total	44	100,805,100	100.00%

Source: USDA Agricultural Statistics, 2005.

reasonably close. Comparing the transactions data for 2004 (76.1 million hogs) with publicly available sources indicates that the individual transactions data account for about 76% of the total industry as reported by the checkoff system (101 million hogs).

To get a more detailed picture of the regional distribution of market hogs, Table 2-2 reports the numbers for the 16 largest production states. The data from all three sources (transactions, checkoff, and USDA) exhibit similar regional patterns, although the absolute numbers are different. According to all three sources, the top two producing states are Iowa (with approximately 31% share) and North Carolina (with between 11% and 16.5% share depending on the source). According to the transactions data and the checkoff data, the third state is Minnesota, and according to the USDA data, the third state is Illinois and Minnesota is fourth.

Table 2-2. Market Hogs by States from Various Sources, 2004

State	Transactions Data	Pork Checkoff Program	USDA[a]
Iowa	24,206,285	28,284,405	29,891,000
North Carolina	D	14,941,334	10,811,300
Minnesota	D	12,530,432	9,089,700
Indiana	D	5,399,740	7,153,100
Oklahoma	D	3,259,726	4,928,800
South Dakota	D	2,221,727	4,690,900
Illinois	D	6,863,046	9,237,100
Virginia	D	1,177,253	3,925,100
Nebraska	D	5,271,858	6,953,300
Pennsylvania	D	1,942,645	2,846,400
Kentucky	D	530,137	2,488,300
California	D	205,578	2,519,700
Mississippi	D	474,921	N/A
Missouri	D	3,963,032	2,042,500
Ohio	D	2,802,273	1,204,900
South Carolina	D	254,501	N/A
Total	76,115,709	90,122,608	97,782,100

[a] Number slaughtered commercially, USDA, NASS (2005).

D = Results suppressed.

2.1.5 Market Hog Price Data

For analysis purposes, the transactions data prices were aggregated. Table A-1 in Appendix A of this volume reports weekly average prices and their standard deviations. Out of 29 plants, 16 reported using liveweight and carcass weight pricing, 9 used only liveweight prices, and the remaining 4 used only carcass weight pricing. The definitions of the variables in Table A-1 are as follows:

(1) avg_hogp_3: average total price (base price + adjustment) when pricing unit is $/cwt liveweight

(2) avg_basep_3: average base price when pricing unit is $/cwt liveweight

(3) avg_hogp_4: average total price (base price + adjustment) when pricing unit is $/cwt carcass weight.

(4) avg_basep_4: average base price when pricing unit is $/cwt carcass weight.

The price data exhibit some interesting features. First, the differences between the minimum and maximum values of weekly average prices are much larger than expected. We expect to see different plants paying different prices for hogs, depending on their location and the type of procurement arrangement used. However, the maximum values are up to three times larger than the minimum values during some weeks.

Second, the regression of average total liveweight price (base price plus adjustment) on average total carcass weight price indicates that the estimated slope coefficient in this regression is 0.8778. Comparatively, the ratio of carcass weight to liveweight ranges from 0.73 to 0.76. The regression of average base liveweight price on the average base carcass weight price shows a very similar estimated slope coefficient of 0.8827. To ensure that the obtained results are not a consequence of an aggregation approach, we reran the above regressions with individual plants' weekly data. Of 16 plants that reported using both pricing units (liveweight and carcass weight), no plant's slope coefficients were comparable with their reported physical yields. Using total prices (base plus adjustments), we found the coefficients ranging from 0.46 to greater than 1.0, with most of them above 0.8. The coefficient larger than unity means a higher price per pound liveweight than per pound carcass weight. Using base prices, we found that the results are quite similar to the results using the total prices.

To further investigate this puzzle, we analyzed the timing of the purchases within each week. The idea is that because most hogs (67%) are purchased on a carcass basis, liveweight pricing, especially when used by large plants, is frequently used to smooth out packing plant scheduling problems.[7] These hogs may be overpriced because they are purchased at the last moment, primarily to fill next week's kill, thus explaining the anomaly we observe. The problem with conducting this analysis arises because, for the majority of observations, the purchase date and the kill date are the same, with some of the recorded dates actually indicating a Sunday. Because both of those data

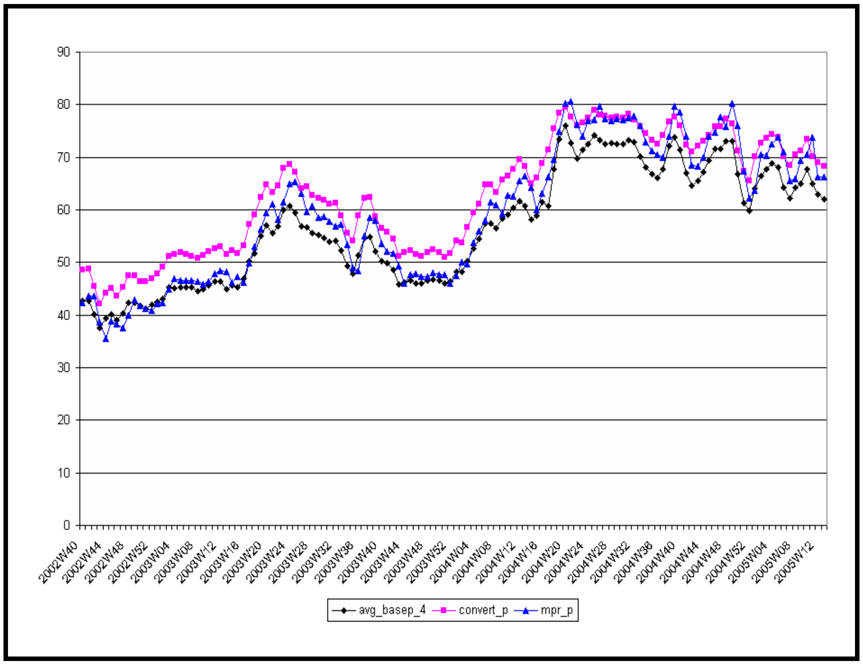
[7] This idea was actually suggested by one of the anonymous peer reviewers.

observations are doubtful, a careful timing analysis would not have been useful. However, regressing the implicit yield (the ratio of live price to carcass price) on a set of daily binary variables indicates that Monday through Thursday implicit yields are significantly smaller than Friday through Sunday yields. This corroborates the hypothesis that near the end of the week, live prices relative to carcass prices tend to be higher than earlier in the week. However, the Monday through Thursday implicit yields are still higher than the actual physical yields, so the timing of the purchases does not explain the anomaly of the unreasonably high live price to carcass price ratios.

Given the discrepancy between liveweight and carcass weight pricing, we worked with the constructed carcass weight prices as discussed above. The last two columns of Table A-1 report the converted carcass price series and, for comparison purposes, the national weighted average base price series from MPR data.[8] We compared the constructed carcass weight prices (convert_p) with the average base price series when the pricing unit was carcass weight (i.e., the originally reported carcass weight price series) (avg_basep_4) and with the national weighted average base price from MPR data (mpr_p). First, we tested the hypotheses of equal means for each pair of prices. As Table A-2 shows, avg_basep_4 and mpr_p have statistically indistinguishable means. The other two pairs have statistically different means. The mean of the constructed carcass weight price series ($62.90/cwt) is larger than the mean of the MPR price series ($59.56), which is understandable because the MPR series includes only the base price, while our constructed series includes the base price plus adjustments. Next, we calculated the Pearson correlation coefficients for each pair of prices; the results are provided in Table A-3. The correlation coefficients are almost all unity, and all P values for the null of zero correlation are less than .0001. This indicates that all three prices are almost perfectly correlated, as seen in Figure 2-1.

[8] This series is from various issues (2002, 2003, and 2004) of USDA's "Annual Meat Trade Review: Meat, Livestock and Slaughter."

Figure 2-1. Comparison of Carcass Weight Hog Price Series From Different Sources, October 2002–September 2005



2.2 VOLUME OF MARKET HOGS TRANSFERRED BY TYPE OF MARKETING ARRANGEMENT

In this section, we determine the volume of market hogs transferred through the types of spot and alternative arrangements by type, size, and location of market participants.

2.2.1 The Importance of Various Marketing Arrangements in Total Purchases and Sales of Hogs

Table 2-3 presents the summary of market hog purchase methods by region from the packers' transactions (purchase) data. In this table, the procurement methods are classified into the following categories:

- § auction barns
- § video/electronic auctions
- § dealers or brokers
- § direct trade (cash or spot market transaction between an individual buyer and seller of livestock within 2 weeks of kill date)
- § procurement or marketing contract (formal agreement specifying terms for transfer of market hogs using prespecified price or payment formula)

Table 2-3. Summary of Market Hog Purchase Methods by Plant Region: Pork Packers’ Transactions (Purchase) Data, October 2002–March 2005

Region	Auction Barns	Video/ Electronic Auctions	Dealers or Brokers	Direct Trade	Procurement or Marketing Contract	Forward Contract	Marketing Agreement	Packer Owned	Other	Missing	Total
East											
Observations	D	0	D	D	D	D	70,307	D	0	D	D
Percentage		0.00%					28.83%		0.00%		
Number of market hogs	D	0	D	D	D	D	10,557,294	D	0	D	D
Percentage of market hogs		0.00%				0.00%	27.64%		0.00%		100.00%
Midwest											
Observations	D	0	41,354	207,319	498,752	170,179	175,646	95,808	D	25,491	1,414,754
Percentage		0.00%	2.92%	14.65%	35.25%	12.03%	12.42%	6.77%		1.80%	100.00%
Number of market hogs	D	0	2,387,863	14,484,372	47,189,061	22,924,220	21,038,919	14,896,056	D	1,380,624	145,469,746
Percentage of market hogs		0.00%	1.64%	9.96%	32.44%	15.76%	14.46%	10.24%		0.95%	100.00%
Other											
Observations	D	D	D	D	D	D	0	D	0	D	D
Percentage							0.00%		0.00%		100.00%
Number of market hogs	D	D	D	D	D	D	0	D	0	D	D
Percentage of market hogs							0.00%		0.00%		100.00%
Total											
Observations	7,852	D	45,026	224,135	530,341	170,196	245,953	231,766	D	25,954	1,677,227
Percentage	0.47%		2.68%	13.36%	31.62%	10.15%	14.66%	13.82%		1.55%	100.00%
Number of market hogs	998,886	D	3,015,746	16,860,654	54,892,478	22,925,829	31,596,213	37,157,144	D	1,449,891	189,481,919
Percentage of market hogs	0.53%		1.59%	8.90%	28.97%	12.10%	16.68%	19.61%		0.77%	100.00%

D = Results suppressed.

- forward contract (oral or written agreement for the future purchase of a specified quantity of livestock; contract is entered into at any time between placement of livestock on feed and 2 weeks prior to kill date)
- marketing agreement (long-term oral or written arrangement where a packer agrees to purchase livestock under specific terms)
- packer owned
- other
- missing

This classification does not specifically address production contracts.[9] Overall, the most important procurement method is marketing contracts, accounting for almost 29% of all market hogs purchased by packers in the data set. The second most important category is packer-owned hogs, accounting for almost 20% of all market hogs procured, and the third category is marketing agreements. The regional picture is quite different from the national averages. In the East region, the most important procurement method is packer-owned hogs, accounting for over 58% of market hogs, followed by marketing agreements and marketing contracts. In the Midwestern region, the picture more closely resembles the national averages.

To compare the volume of hogs by marketing arrangement from the transactions data, the producer survey, and the packer survey, we combined the procurement methods into broader categories. These results are presented in Tables 2-4a, 2-4b, and 2-4c. The “cash/spot” category includes auction barns, video/electronic auctions, dealers or brokers, and direct trade; “marketing contracts” include procurement or marketing contracts, forward contracts, and marketing agreements; “internal\production” includes internal transfers, packer-owned hogs, and production contracts (in the surveys); and “other” combines the remaining categories (other, sold through

[9] Production contract settlement data were requested separately from transactions data because of the distinctly different type of data. However, all data were collected at the plant level, not the company level. Therefore, individual plants that did not maintain their own production contracts were unable to provide settlement data. In these situations, production contract hogs were included in the transactions data, but they are typically included in the “other” category.

Table 2-4a. Summary of Market Hog Volume by Marketing Arrangement and Region: Pork Producers' Survey

Marketing Arrangement	East			Midwest			Other			All[a]		
	Number of Producers	Number of Market Hogs	Percent-age	Number of Producers	Number of Market Hogs	Percent-age	Number of Producers	Number of Market Hogs	Percent-age	Number of Producers	Number of Market Hogs	Percent-age
Pork Producers' Survey Data (Based on Q6.2[b] Without Using Survey Weights)												
Cash/spot	D	D		117	459,871	16.6%	D	D		133	510,741	14.6%
Marketing contract	3	260,000	53.1%	57	2,234,620	80.5%	4	204,226	88.3%	64	2,698,847	77.2%
Internal/production	D	D		9	68,894	2.5%	D	D		16	274,303	7.8%
Other	0	0	0.0%	4	14,021	0.5%	0	0	0.0%	4	14,021	0.4%
Total	15	489,222	100.0%	187	2,777,406	100.0%	15	231,283	100.0%	217[c]	3,497,911	100.0%
Pork Producers' Survey Data (Based on Q6.2[b] Using the Modified Survey Weights)												
Cash/spot	D	5,005,966	26.7%	117	18,277,978	23.9%	D	821,879	18.4%	133	24,105,823	24.2%
Marketing contract	3	5,439,792	29.1%	57	51,609,434	67.6%	4	3,512,857	78.5%	64	60,562,083	60.8%
Internal/production	D	8,273,398	44.2%	9	5,416,695	7.1%	D	142,711	3.2%	16	13,832,804	13.9%
Other	0	0	0.0%	4	1,042,822	1.4%	0	0	0.0%	4	1,042,822	1.0%
Total	15	18,719,156	100.0%	187	76,346,930	100.0%	15	4,477,447	100.0%	217[c]	99,543,533	100.0%

[a] Because of nonresponse in Q6.2, the total number of market hogs here is less than the totals in Table 2-1a.

[b] Q6.2: What methods for selling or shipping pigs and hogs[d] are used by your operation? Enter the percentage of total head.

[c] Because producers can be counted multiple times, this total is not the same as the total in Table 2-1a.

[d] Because Q6.2 is about general pigs and hogs, it does not perfectly reflect the methods for selling or shipping market hogs.

D = Results suppressed.

Table 2-4b. Summary of Market Hog Volume by Marketing Arrangement and Region: Pork Packers' Survey

Marketing Arrangement	East			Midwest			Other			All[a]		
	Number of Producers	Number of Market Hogs	Percent-age	Number of Producers	Number of Market Hogs	Percent-age	Number of Producers	Number of Market Hogs	Percent-age	Number of Producers	Number of Market Hogs	Percent-age
Pork Packers' Survey Data (Based on Q2.2[b] Without Using Survey Weights)												
Cash/spot	21	1,281,970	8.7%	28	15,986,481	27.4%	24	259,702	9.3%	73	17,528,153	23.1%
Marketing contract	8	10,911,282	73.6%	19	36,297,283	62.3%	9	2,119,903	75.6%	36	49,328,467	65.0%
Internal/production	3	2,626,006	17.7%	6	6,013,680	10.3%	5	424,574	15.1%	14	9,064,259	11.9%
Other	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Total	32	14,819,258	100.0%	53	58,297,443	100.0%	38	2,804,179	100.0%	123[c]	75,920,880	100.0%
Pork Packers' Survey Data (Based on Q2.2[b] Using the Modified Survey Weights)												
Cash/spot	21	1,716,684	9.2%	28	21,079,519	28.3%	24	1,191,798	15.5%	73	23,988,000	23.8%
Marketing contract	8	13,705,067	73.2%	19	46,305,187	62.2%	9	5,427,105	70.6%	36	65,437,359	64.9%
Internal/production	3	3,296,471	17.6%	6	7,002,615	9.4%	5	1,066,246	13.9%	14	11,365,332	11.3%
Other	0	0	0.0%	0	0	0.0%	0	0	0.0%	0	0	0.0%
Total	32	18,718,221	100.0%	53	74,387,321	100.0%	38	7,685,149	100.0%	123	100,790,691	100.0%

[a] Q2.2: What methods are used by your plant for procuring market hogs?

[b] Since packers can be counted multiple times, this total is not same as the total in Table 2-1b.

[c] Because of nonresponse in Q2.2, total number of market hogs here are less than the totals in Table 2-1b.

Table 2-4c. Summary of Market Hog Volume by Marketing Arrangement and Region: Pork Packer Transactions Data, October 2002–March 2005

Marketing Arrangement	East			Midwest			Other			All		
	No. of Observa-tions	Number of Market Hogs	Percent-age	No. of Observa-tions	Number of Market Hogs	Percent-age	No. of Observa-tions	Number of Market Hogs	Percent-age	No. of Observa-tions	Number of Market Hogs	Percent-age
Pork Packers Transaction (Purchase) Data, October 2002–March 2005												
Cash/spot	D	D		253,536	17,574,147	12.1%	D	D		277,675	20,993,645	11.1%
Marketing contract	D	D		844,577	91,152,200	62.7%	D	D		946,490	109,414,520	57.7%
Internal/production	D	D		95,808	14,896,056	10.2%	D	D		231,766	37,157,144	19.6%
Other	D	D		220,833	21,847,343	15.0%	D	D		221,296	21,916,610	11.6%
Total	D	D	100.0%	1,414,754	145,469,746	100.0%	D	D	100.0%	1,677,227	189,481,919	100.0%

D = Results suppressed.

co-op,[10] and missing). According to all three data sources, the marketing contract is the most widely used purchase method in the hog industry. Using the raw data, the producers' survey indicates that marketing contracts' share is 77%, the packers' survey shows this share is 65%, and this share is 58% in the packers' transactions data. When we consider the modified survey weights, the marketing contract share is 61% in the producers' survey and 65% in the packers' survey. The second most important procurement method in both surveys is the cash/spot method with a 15% share reported by producers and 23% share reported by packers using raw data. The modified survey weights show the shares are 24% for both producer and packer surveys. The second most important method according to the transactions data is internal\production with a 20% share, whereas the cash/spot method is third with 11%.

Discrepancies between the survey data and the individual transactions data exist; however, it is important to note that the survey results contain a stratified sample of all packers, whereas the transactions data are from large packers only. Therefore, differences in the data sets may result from large packers' procurement methods not being representative of the entire industry. If this is true, then it appears that cash/spot marketing arrangements seem to be more important for small packers than for large packers, which seems to support the intuition and anecdotal evidence. We analyze variations in marketing arrangements by size of the operation in more detail in Section 2.2.

Tables 2-4a through 2-4c also provide a breakdown of volumes by region. Both surveys indicate that marketing contracts are the most frequently used procurement method in all regions, using raw data. For the East region, the packer survey summary indicates that marketing contracts account for 73% of all purchases, internal/production represents 18%, and the remaining 9% are from cash/spot purchases. However, the transactions data summary indicates that internal/production accounts for the majority of purchases, marketing contracts represent a moderate percentage, and a very small percentage is cash/spot purchases. The weighted producer survey responses confirm the ranking of marketing arrangements in the transactions data.

[10] This category is available only in the pork producers' survey data set.

In the Midwest region, weighted packer and producer surveys indicate that marketing contracts account for 62% to 68% of purchases, cash/spot purchases represent 24% to 28% of purchases, and 7% to 9% of purchases are through internal/production arrangements. Transactions data from the Midwest show that 63% of purchases are from marketing contracts, 12% are cash/spot, 10% are internal/production, and 15% are from other arrangements.

Finally, in other states all three data sources show marketing contracts and cash/spot are the most frequently used marketing arrangements. However, the percentage of market share varied significantly depending on the data source.

2.2.2 Variations in Marketing Arrangements due to Size and Type of the Operation

Because of the differences between the packers' survey results and the packers' individual transactions data, we split the survey results into size categories for more direct comparisons. Pork producers that had an annual revenue of $2.5 million or more were classified as large; otherwise, they were considered small. Pork packers that had a weekly slaughter capacity of 6,000 head or more were classified as large; otherwise they were classified as small. The 6,000-head cutoff point was derived from the installed capacity reported by packers in the individual transactions data set. This new definition of large packers should match the packers' survey results more precisely with the individual transactions data results. For ease of exposition, we continue to use the aggregated procurement methods defined in Section 2.2.1.

Table 2-5a summarizes producer sales methods by size and the marketing arrangements they use from the pork producers' survey. We present the results with raw survey data and the results using modified survey weights. Using modified survey weights, we see that, among the large producers, 81% of market hogs were sold through marketing contracts and 9% were sold through cash/spot market sales. Small producers tend to use more cash/spot sales than large producers; 50% of market hogs were sold through marketing contracts and 33% through cash/spot market sales. The results based on the raw survey numbers are similar.

Table 2-5b summarizes the packers' survey results for market hog purchase methods by size of the pork packer. According to

Table 2-5a. Market Hog Sales Methods by Size: Pork Producers' Survey

Sales Method	Large[a]			Small			All		
	Number of Producers	Number of Market Hogs	Percentage	Number of Producers	Number of Market Hogs	Percentage	Number of Producers	Number of Market Hogs	Percentage
Pork Producers' Survey Data (Based on Q6.1.c) Without Using Survey Weights									
Cash/spot	9	271,162	9.9%	124	239,579	31.5%	133	510,741	14.6%
Marketing contract	10	2,294,101	83.8%	54	404,746	53.2%	64	2,698,847	77.2%
Internal/production	3	172,489	6.3%	13	101,814	13.4%	16	274,303	7.8%
Other	0	0	0.0%	186	14,021	1.8%	186	14,021	0.4%
Total	22	2,737,752	100.0%	377	760,159	100.0%	399	3,497,911	100.0%
Pork Producers' Survey Data (Based on Q6.1.c) Using the Modified Survey Weights									
Cash/spot	9	2,991,838	8.7%	124	21,113,985	32.5%	133	24,105,823	24.2%
Marketing contract	10	27,946,515	81.0%	54	32,615,568	50.1%	64	60,562,083	60.8%
Internal/production	3	3,542,351	10.3%	13	10,290,453	15.8%	16	13,832,804	13.9%
Other	0	0	0.0%	186	1,042,822	1.6%	186	1,042,822	1.0%
Total	22	34,480,704	100.0%	377	65,062,828	100.0%	399	99,543,532	100.0%

[a] Large pork producers have annual revenues of $2.5 million or more.

Table 2-5b. Market Hog Purchase Methods by Size: Pork Packers' Survey

Purchase Method	Large[a] Number of Producers	Large[a] Number of Market Hogs	Large[a] Percentage	Small Number of Producers	Small Number of Market Hogs	Small Percentage	All Number of Producers	All Number of Market Hogs	All Percentage
Pork Packers' Survey Data (Based on Q1.4) Without Using Survey Weights									
Cash/spot	28	17,116,966	22.7%	45	411,188	89.1%	73	17,528,154	23.1%
Marketing contract	29	49,279,522	65.3%	7	48,945	10.6%	36	49,328,467	65.0%
Internal/production	10	9,062,677	12.0%	4	1,582	0.3%	14	9,064,259	11.9%
Other	0	0	0.0%	0	0	0.0%	0	0	0.0%
Total	33	75,459,165	100.0%	52	461,715	100.0%	52	75,920,880	100.0%
Pork Packers' Survey Data (Based on Q1.4) Using the Modified Survey Weights									
Cash/spot	28	22,404,550	22.6%	45	1,583,451	86.2%	73	23,988,000	23.8%
Marketing contract	29	65,191,657	65.9%	7	245,702	13.4%	36	65,437,359	64.9%
Internal/production	10	11,356,909	11.5%	4	8,423	0.5%	14	11,365,332	11.3%
Other	0	0	0.0%	0	0	0.0%	0	0	0.0%
Total	33	98,953,116	100.0%	52	1,837,575	100.0%	52	100,790,691	100.0%

[a] Large pork packers have weekly slaughter capacity (for market hogs) of 6,000 head or more.

the survey data for large packers, marketing contracts are the most widely used procurement method with 66%, followed by cash/spot market sales with 23%, and packer owned and production contracts with 12%. The difference between these shares and the individual transactions data shares (Table 2-4c) mainly comes from the fact that a large percentage of packers' transactions were listed in the category "other or missing" (close to 12%); as a result, the shares of marketing contracts—58%—and cash/spot markets—11%—are lower, but the share of internal/production—20%—is larger than in the survey. Small packers essentially use only two procurement channels. Cash/spot market purchases is the most frequently used method—86%, followed by marketing contracts—13%.

Table 2-6 shows the breakdown of market hog sales methods by pork producers' type of operation from the producers' survey. Pork producers classified as independent growers produced almost 50% of market hogs, contract growers produced 12% of market hogs, hog integrators produced 27% of market hogs, and multitype producers produced about 9%.[11] The most popular avenue for selling hogs among independent growers was marketing contracts, followed by cash/spot market sales. As expected, contract growers sold most of their hogs through production contract settlements (83% of contract grower hogs). A small percentage of contract grower hogs were sold through cash/spot markets or marketing contracts. Hog integrators sold 83% of their hogs through marketing contracts and the rest through cash/spot markets and production contracts. Finally, multitype producers divide their sales between the cash/spot market category and marketing contracts.

2.3 PRICING OF MARKET HOGS BY TYPE OF MARKETING ARRANGEMENT

The analyses in this section are based on pork packers' individual transactions data for the full sample period—October 2002 to March 2005. Because the survey instruments did not contain pricing questions, the survey data could not be used for the analyses. In this section, we analyze pricing methods used by packers; report average price levels and differences in price

[11] Multitype producers are those who chose multiple answers in Question 1.2 in the survey, and the producers who did not respond to Question 1.2 are classified as not specified.

Table 2-6. Market Hog Sales Methods by Type of Pork Producer (Based on Q1.2[a])

Type of Pork Producer	Cash/Spot	Marketing Contract	Internal/ Production	Other	Total
Raw Numbers Without Using Survey Weights					
Independent grower					
Number of producers	117	D	D	156	319
Number of market hogs	329,300	D	D	14,021	1,119,340
Percentage	9.4%			0.4%	32.0%
Contract grower					
Number of producers	D	D	10	0	16
Number of market hogs	D	D	125,920	0	151,220
Percentage			3.6%	0.0%	4.3%
Hog integrator					
Number of producers	D	9	D	0	16
Number of market hogs	D	1,845,666	D	0	2,100,461
Percentage		52.8%		0.0%	60.0%
Multitype					
Number of producers	5	5	0	0	10
Number of market hogs	39,130	66,100	0	0	105,230
Percentage	1.1%	1.9%	0.0%	0.0%	3.0%
Not specified					
Number of producers	D	D	0	0	8
Number of market hogs	D	D	0	0	21,660
Percentage			0.0%	0.0%	0.6%
All					
Number of producers	133	64	16	156	369
Number of market hogs	510,741	2,698,847	274,303	14,021	3,497,911
Percentage	14.6%	77.2%	7.8%	0.4%	100.0%
Weighted Sums Using the Modified Survey Weights					
Independent grower					
Number of producers	117	D	D	156	319
Number of market hogs	15,601,104	32,369,633	506,759	1,042,822	49,520,318
Percentage	15.7%	32.5%	0.5%	1.0%	49.7%
Contract grower					
Number of producers	D	D	10	0	16
Number of market hogs	758,632	1,351,905	10,146,010	0	12,256,547
Percentage	0.8%	1.4%	10.2%	0.0%	12.3%

(continued)

Table 2-6. Market Hog Sales Methods by the Type of Pork Producers (Based on Q1.2[a]) (continued)

Type of Pork Producer	Cash/Spot	Marketing Contract	Internal/ Production	Other	Total
Hog integrator					
Number of producers	D	9	D	0	16
Number of market hogs	1,417,368	22,705,650	3,180,036	0	27,303,054
Percentage	1.4%	22.8%	3.2%	0.0%	27.4%
Multitype					
Number of producers	5	5	0	0	10
Number of market hogs	4,916,151	3,928,502	0	0	8,844,653
Percentage	4.9%	3.9%	0.0%	0.0%	8.9%
Not specified					
Number of producers	D	D	0	0	8
Number of market hogs	1,412,568	206,393	0	0	1,618,960
Percentage	1.4%	0.2%	0.0%	0.0%	1.6%
All					
Number of producers	133	64	16	156	369
Number of market hogs	24,105,823	60,562,083	13,832,804	1,042,822	99,543,533
Percentage	24.2%	60.8%	13.9%	1.0%	100.0%

[a] Q1.2: Which of the following describe your operation during the past year?

D = Results suppressed.

levels associated with various marketing arrangements, adjusting for relevant factors that can affect prices; and provide economic interpretation for the phenomena that we observe. We also examine whether price differences vary with market conditions, such as changes in consumer demand and feed costs.

2.3.1 Pricing Methods

Table 2-7 reports market hog purchases by pricing methods and plant region. The pricing methods are categorized as follows: individually negotiated pricing (negotiations between a buyer and seller, excluding negotiated formula pricing)—8% of total market hogs; public auction—0.4%; formula pricing (using another price as the base for the purchase of livestock)—57%; internal transfer (transfer of packer-owned livestock from a finisher to the slaughter plant)—19%, and other (pricing method not captured in other categories)—14%. There are stark differences in pricing methods between the East and Midwest regions, which clearly reflects the difference in the

Table 2-7. Summary of Market Hog Pricing Methods by Region: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

Region	Individually Negotiated Pricing	Public Auction	Formula Pricing	Internal Transfer	Other	Missing	Total
East							
Observations	2,607	D	104,846	D	0	D	D
Percentage	1.07%		42.99%		0.00%		100.00%
Number of market hogs	412,037	D	15,459,198	D	0	D	D
Percentage of market hogs	1.08%		40.47%		0.00%		100.00%
Midwest							
Observations	212,729	D	843,134	D	262,526	D	1,414,754
Percentage	15.04%		59.60%		18.56%		100.00%
Number of market hogs	14,933,500	D	88,948,186	D	26,464,282	D	145,469,746
Percentage of market hogs	10.27%		61.15%		18.19%		100.00%
Other							
Observations	0	0	D	0	0	D	D
Percentage	0.00%	0.00%		0.00%	0.00%		100.00%
Number of market hogs	0	0	D	0	0	D	D
Percentage of market hogs	0.00%	0.00%		0.00%	0.00%		100.00%
Total							
Observations	215,336	4,892	951,642	226,437	262,526	16,394	1,677,227
Percentage	12.84%	0.29%	56.74%	13.50%	15.65%	0.98%	100.00%
Number of market hogs	15,345,537	703,662	107,862,399	36,619,116	26,464,282	2,486,923	189,481,919
Percentage of market hogs	8.10%	0.37%	56.92%	19.33%	13.97%	1.31%	100.00%

D = Results suppressed.

industry structure. In the East, the majority of their market hogs were priced using internal transfer, 40% were priced using formula pricing, and 1% were priced using individually negotiated pricing. In the Midwest, 61% of their market hogs are priced using formula pricing, 10% were priced using individually negotiated pricing, and a small percentage were priced using internal company transfers. In other areas, formula pricing was the dominant pricing method. The remaining hogs purchased in this area did not have a pricing method reported.

Table 2-8 summarizes the details of the formula pricing method (formula base), in cases where formula pricing was used. The results indicate that most formula pricing was based on USDA dressed or carcass quotes (57%). Other frequently used formula base prices include the CME futures prices and USDA live quotes (a majority of formula purchases in other states). The total number of market hogs in each region in Table 2-8 does not match the number of market hogs under formula pricing in Table 2-7. Packers provided information on the formula base even though the pricing method used was not formula pricing.[12]

2.3.2 Price Differences across Marketing Arrangements

Table 2-9 shows the average price of market hogs (in dollars per hundred pounds carcass weight) by region. During the full sample period and for the calendar year 2004, the Midwest region had the highest hog price ($73.24 in 2004), the Other region had the second highest, and the East region had the lowest price ($60.85 in 2004). Table 2-10 presents the average hog price by procurement method and plant region. Ignoring the “other” and “not specified,” categories the largest average price during the period was associated with procurement or marketing contracts ($64.31/cwt) and the lowest price was associated with packer-owned hogs. The table is also useful for figuring out the relative importance of various purchase methods in total packers’ procurements. The procurement or marketing contract that exhibits the highest price is also associated with the highest number of individual transactions (lots), with 32% of the total number of purchases (individual transactions) recorded through this channel. This percentage must not be confused with the total number of hogs purchased through procurement or[13] marketing contracts, because not all lots contain the same number of hogs.

[12] For example, internal transfer pricing may use an external price source; therefore, the pricing method would be internal transfer, but a formula base would still be applicable.

[13] Table 2-3 shows that procurement or marketing contracts accounted for 32% of all observations, but only 29% of all hogs.

Table 2-8. Summary of Market Hog Formula Bases by Region: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005 and 2004

Region	Individual or Multiple Plant Average Price	USDA Live Quote	USDA Dressed or Carcass Quote	USDA Boxed Pork Price	Chicago Mercantile Exchange Lean Hog Futures	Other Market Price	Other	Missing	Total
East									
Observations	0	D	219,597	0	D	0	4,995	D	D
Percentage	0.00%		90.05%	0.00%		0.00%	2.05%		100.00%
Number of market Hogs	0	D	34,194,974	0	D	0	876,571	D	D
Percentage of market hogs	0.00%		89.52%	0.00%		0.00%	2.29%		100.00%
Midwest									
Observations	D	D	739,158	D	D	D	96,806	405,312	1,414,754
Percentage			52.25%				6.84%	28.65%	100.00%
Number of market Hogs	D	D	73,330,824	D	D	D	9,888,890	40,569,951	145,469,746
Percentage of market hogs			50.41%				6.80%	27.89%	100.00%
Other									
Observations	0	D	0	0	0	0	0	D	D
Percentage	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%		100.00%
Number of market Hogs	0	D	0	0	0	0	0	D	D
Percentage of market hogs	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%		100.00%
Total									
Observations	D	21,891	958,755	D	154,755	D	101,801	421,850	1,677,227
Percentage		1.31%	57.16%		9.23%		6.07%	25.15%	100.00%
Number of market Hogs	D	4,471,370	107,525,798	D	21,144,541	D	10,765,461	43,153,826	189,481,919
Percentage of market hogs		2.36%	56.75%		11.16%		5.68%	22.77%	100.00%

D = Results suppressed.

Table 2-9. Hog Price of Market Hogs by Plant Region: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005 and 2004

	October 2002–March 2005			2004		
Region	Number of Records	Hog Price (mean)[a]	Standard Deviation	Number of Records	Hog Price (mean)[a]	Standard Deviation
East	D	53.04	14.36	D	60.85	12.45
Midwest	1,414,754	64.10	13.78	544,231	73.24	12.94
Other	D	D	D	D	D	D
All	1,677,227	62.46	14.36	655,153	71.21	12.07

[a] Hog price is measured by dollars per hundred weight (cwt), carcass weight.

D = Results suppressed.

There are some differences in the average prices paid by packers across regions. The highest price in the East region was paid for market hogs coming from forward contracts, and the lowest price was paid for packer-owned hogs. In the Midwest, the highest price was paid for hogs coming through procurement or marketing contracts ($64.14), and the lowest price was for hogs acquired through auction barns. If we aggregate auction barns, video/electronic auctions, dealers and brokers, and direct trades into a joint spot/cash market transactions category, the average national cash/spot market price for the entire period was $59.40/cwt (std. dev.=13.41), with rather small differences across regions. The mean cash price was $58.53/cwt (std. dev.=15.89) in the East region and $59.36/cwt (std. dev.=13.26) in the Midwest region.

The primary cause for the regional difference in prices between the East and the rest of the country is the composition of AMAs used by packers to procure their hogs. The mean price of packer-owned hogs in the East is lower than the national average price of $54.66. Packer-owned hogs account for a majority of all hog purchases in this region. The recorded packer owned price represents an internal transfer price and, as such, may not represent an arms-length transaction. Therefore, the regional differences in prices may not necessarily mean that these regions constitute separate markets. In fact, based on the cash/spot market, the dealer or broker price in the East is actually higher than the national average, whereas the direct trade price is still lower than the national average, but the difference is only about $3/cwt carcass weight.

Table 2-10. Average Hog Price by Procurement Method and Plant Region, October 2002–March 2005

Region	Auction Barns	Video/ Electronic Auctions	Dealers or Brokers	Direct Trade	Procurement or Marketing Contract	Forward Contract	Marketing Agreement	Packer Owned	Other	Not Specified	All
East											
Observations	D	0	D	D	D	D	70,307	D	0	D	D
Percentage		0.00%					28.83%		0.00%		100.00%
Hog price (mean)	D	$0.00	D	$56.99	$67.21	D	$56.32	D	$0.00	D	$53.04
Standard deviation	D	0.00	D	16.09	9.10	D	15.21	D	0.00	D	14.36
Midwest											
Observations	D	0	41,354	207,319	498,752	170,179	175,646	95,808	D	25,491	1,414,754
Percentage		0.00%	2.92%	14.65%	35.25%	12.03%	12.42%	6.77%		1.80%	100.00%
Hog price (mean)	D	$0.00	$57.89	$59.69	$64.14	$61.02	$62.53	$64.11	D	$57.89	$64.10
Standard deviation	D	0.00	13.03	13.29	13.37	11.30	11.45	12.90	D	12.18	13.78
Other											
Observations	D	D	D	D	D	D	0	D	0	D	D
Percentage							0.00%		0.00%		100.00%
Hog price (mean)	D	D	D	D	D	D	$0.00	D	$0.00	D	D
Standard deviation	D	D	D	D	D	D	0.00	D	0.00	D	D
All											
Observations	7,852	D	45,026	224,135	530,341	170,196	245,953	231,766	D	25,954	1,677,227
Percentage	0.47%		2.68%	13.36%	31.62%	10.15%	14.66%	13.82%		1.55%	100.00%
Hog price (mean)	$59.52	D	$58.04	$59.66	$64.31	$61.02	$60.76	$54.66	D	$58.07	$62.46
Standard deviation	12.48	D	12.87	13.22	13.20	11.30	12.95	14.64	D	12.24	14.36

D = Results suppressed.

Table 2-11 shows the average hog price by ownership method. As indicated by the percentage of observations in various categories, the vast majority of the total number of lots (and market hogs) were purchased under sole ownership in all regions. Sole ownership tends to have a lower average hog price than other ownership methods, but because the number of observations in all other methods is very small, this result should not be given too much credence.

Table 2-11. Summary of Hog Prices by Ownership Method and Region: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

Region	Sole Ownership	Joint Venture	Shared Ownership	Other	Missing	All
East						
Observations	236,476	D	0	D	D	D
Percentage	96.97%		0.00%			100.00%
Hog price (mean)	$52.77	D	$0.00	D	D	$53.04
Standard deviation	14.33	D	0.00	D	D	14.36
Midwest						
Observations	1,367,266	0	D	D	D	1,414,754
Percentage	96.64%	0.00%				100.00%
Hog price (mean)	$64.44	$0.00	D	D	D	$64.10
Standard deviation	13.81	0.00	D	D	D	13.78
Other						
Observations	D	0	0	0	D	D
Percentage		0.00%	0.00%	0.00%		100.00%
Hog price (mean)	D	$0	$0	$0	D	D
Standard deviation	D	0.00	0.00	0.00	D	D
All						
Observations	1,622,357	D	D	D	43,812	1,677,227
Percentage	96.73%				2.61%	100.00%
Hog price (mean)	$62.71	D	D	D	$53.39	$62.46
Standard deviation	14.45	D	D	D	6.86	14.36

D = Results suppressed.

2.3.3 Explaining the Observed Differences in Prices

To see what other factors may explain the observed differences in prices, we looked at the differences in prices across lot sizes, quality characteristics, and sizes of plants and companies. The results are summarized in Tables 2-12 through 2-15. The results indicate that prices are inversely related to the lot size. Packers seem to pay significantly lower prices for large lots. The highest mean price ($63.13/cwt) was paid for hogs in lots

Table 2-12. Price of Market Hogs by Lot Size: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

Lot Size (Number of Market Hogs)	Number of Records	Hog Price (mean)[a]	Standard Deviation
Fewer than 50	535,078	62.85	14.34
Between 50 and 100	257,603	63.13	14.08
Between 101 and 200	855,998	62.04	14.45
Greater than 200	28,548	61.77	14.31
All	1,677,227	62.46	14.36

[a] Hog price is reported in dollars per hundred pounds (cwt), carcass weight.

Table 2-13. Price of Market Hogs by Quality Attribute (Loin-Eye Depth): Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

Quality (Loin-Eye Depth [mm])[a]	Number of Records	Hog Price (mean)[b]	Standard Deviation
Less than 55.3	368,109	61.27	15.03
Between 55.3 and 66.3	776,617	62.43	15.26
Greater than 66.3	392,056	62.70	12.92
Missing	140,445	—	—
All	1,677,227	62.46	14.36

[a] These classifications are based on the interquartile ranges of loin-eye depth.

[b] Hog price is reported in dollars per hundred pounds (cwt), carcass weight.

Table 2-14. Price of Market Hogs by Weekly Slaughter Capacity: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

Capacity (Weekly Maximum Slaughter Capacity)[a]	Number of Records	Hog Price (mean)[b]	Standard Deviation
Fewer than 41,000	104,366	63.36	13.06
Between 41,000 and 95,000	704,346	61.73	13.77
Greater than 95,000	868,515	62.95	14.94
All	1,677,227	62.46	14.36

[a] These classifications are based on the interquartile ranges of weekly slaughter capacity.

[b] Hog price is reported in dollars per hundred pounds (cwt), carcass weight.

Table 2-15. Price of Market Hogs by Company Size: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

Company Size[a]	Number of Records	Hog Price (Mean)[b]	Standard Deviation
5 or more plants	D	D	D
2 to 4 plants	556,886	68.13	14.18
Single plant	D	62.55	12.29
All	1,677,227	62.46	14.36

[a] Company size is the number of plants owned by the company.

[b] Hog price is measured by dollars per hundred weight (cwt), carcass weight.

D = Results suppressed.

of 50 to 100 head. Prices also seem to respond to quality differences. The only quality attribute available for a sufficiently large number of observations was loin-eye depth.[14] Loin-eye depth is measured in millimeters and the greater value implies the higher quality of market hogs. Higher prices are clearly associated with higher loin-eye depth. Looking at the weekly slaughter capacities of plants, we see the lowest prices for market hogs were paid by plants in the middle of the capacity range (41,000 to 95,000 hogs slaughtered weekly). Finally, we looked at the relationship between the company size and the prices paid for live market hogs, as perhaps some preliminary indication of market power. We divided the sample of 29 plants into three groups: the first group contains companies with five or more plants, the second group contains companies with two to four plants, and the last group contains single-plant companies. Although the specific value is suppressed for confidentiality, the group containing five or more plants per company paid the lowest price on average.

To explore the determinants of the price differences in a more systematic way, we estimate a model similar in spirit to the performance approach used to test for complementarity of marketing arrangements in Section 3 of this report. The approach involves regressing a firm-level performance measure on portfolios of marketing arrangements and a vector of exogenous control variables X. In this context, the performance measure is the price that plants pay to procure their hogs, with the idea being that certain favorable combinations of marketing

[14] In Section 4 of this report, we talk extensively about the quality differences associated with various AMAs.

arrangements may actually result in a lower average price paid to procure hogs.

Once the procurement strategy (i.e., portfolio of marketing arrangements) is in place, plants do not change it very often.[15] Therefore the portfolio indicators in our model do not change during the sample period. However, different hogs are purchased through different channels, so each lot is associated with a particular marketing arrangement through which it was procured. Overall, the price of a lot of hogs is determined by the portfolio of marketing arrangements that a firm has in place, as well as by the individual marketing arrangement through which the particular lot was purchased. To capture both effects, we estimated the following linear regression model:

$$P\_carcass = f(D\_MA, D\_portfolio, X), \qquad (2.1)$$

where P_carcass is the weekly average of the carcass prices (in $/cwt) paid by the packers in the data set. D_MA = (d_ma1, d_ma2, ..., d_ma4) is a vector of binary variables for marketing arrangement categories defined as follows:

- d_ma1 = 1 if procurement method is cash/spot sales (MA1); 0, otherwise
- d_ma2 = 1 if procurement method is marketing contract (MA2); 0, otherwise
- d_ma3 = 1 if procurement method is packer owned (MA3); 0, otherwise
- d_ma4 = 1 if procurement method is other (MA4); 0, otherwise

D_portfolio is the set of binary variables for each of the observed portfolios of marketing arrangements used by the plant during the data period. There are 15 possible combinations of marketing arrangements, but only 5 combinations are actually observed; hence, the portfolio binary variables are defined as follows:

- pfbin1 = 1 if only cash/spot is used; 0, otherwise

[15] Moreover, the data reveals an interesting fact that all plants owned by the same company use the same portfolio of AMAs to procure their hogs. This is a clear indication that the procurement strategy is decided at the company level and not at the plant level.

§ pfbin2 = 1 if only marketing contracts is used; 0, otherwise

§ pfbin3 = 1 if only cash/spot and marketing contracts are used; 0, otherwise

§ pfbin4 = 1 if only cash/spot, marketing contracts, and packer owned are used; 0, otherwise

§ pfbin5 = 1 if only marketing contracts, packer owned, and other marketing arrangements are used; 0, otherwise

The exogenous variables included in the regression are regional binary variables, two animal characteristics variables—the loin-eye depth (Loineye) and the liveweight (in pounds) of the market hogs per head (Livew), and time and time squared variables. Quadratic time trend is included in the regression to pick up all possible macro-economic influences (e.g., inflation) that may be affecting the hog price.

Table 2-16 summarizes the ordinary least squares (OLS) regression results. Because of the additional elimination of outliers and missing values of some explanatory variables, an additional 154,469 observations were excluded, so the final sample size used in this regression is 1,522,758. We omitted the binary variable for cash/spot sales (d_ma1) and the binary variable for the cash/spot-only portfolio (pfbin1).

All the estimates for individual coefficients are significant at the 1% significance level, which is not surprising given the sample size. The signs of the coefficients on the procurement method variables are consistent with the previous findings. On average, the price of marketing contract purchases (MA2) is higher than cash/spot purchases (MA1) by $0.75/cwt, while the packer owned price (MA3) is about $0.88/cwt lower than the cash/spot price. The actual means of the data are $59.40/cwt for cash/spot, $62.79/cwt for marketing contracts, and $54.66/cwt for packer owned. The sign of the regional variable R1 shows that the East region has a lower average price than the rest of the country by $10.50/cwt. The sign of the loin-eye depth variable is positive and significant. Thicker loin-eye depth indicates higher quality hogs, and higher quality hogs are sold at higher prices. The sign of Livew (liveweight per head) is negative and statistically significant. The magnitudes of both coefficients are small and thus have little influence on the average hog price.

Table 2-16. OLS Regression Analysis of Hog Prices: Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

Variable	Parameter Estimate	Standard Error	t value	P value
Intercept	53.518	0.1223	437.35	<.0001
D_ma2	0.746	0.0227	32.81	<.0001
D_ma3	–0.875	0.0296	–29.54	<.0001
D_ma4	1.561	0.0460	33.96	<.0001
R1[a]	–10.486	0.0262	–399.83	<.0001
pfbin2	4.341	0.1512	28.72	.8260
pfbin3	0.734	0.0585	12.55	<.0001
Pfbin4	–1.750	0.0553	–31.65	<.0001
Pfbin5	13.899	0.0663	209.66	<.0001
Loin-eye depth (mm)	0.013	0.0016	8.41	<.0001
Liveweight per head (lb)	–0.047	0.0005	–103.55	<.0001
Time	0.055	0.0001	528.25	<.0001
Time squared	–2.123	0.0111	–191.63	<.0001
Adjusted R^2	0.670			

[a] Regional binary variable R1 = 1 if region is East; R1 = 0, otherwise.

In estimating the effect of various factors to explain the behavior of hog price, it is necessary to avoid any possible selection bias coming from nonrandom selection of marketing arrangement portfolios. The decision about the optimal portfolio of marketing arrangements is a company's strategic decision, and it is possible that companies with more capable management would organize their procurement service by selecting more appropriate marketing arrangement portfolios. Because the adoption of different procurement portfolios is likely to be nonrandom, the endogeneity problem needs to be addressed. Thus, we use the instrumental variable estimator (two-stage least squares [2SLS]).[16] Because we have four endogenous variables (portfolios 2, 3, 4, and 5) we need at least four instruments. We use the size of the company, as measured by the number of plants that it operates, the plant capacity, and its location. Capacity is the plant's maximum slaughter capacity per week for market hogs, not the actual

[16] For a detailed discussion about various approaches to address the endogeneity problem in a similar context, see the discussion in Section 3.3.

slaughter volume.[17] Location was introduced via the binary variable for the Midwest region. To capture possible nonlinearities, we also use the size squared, the capacity squared, and the interaction of size and capacity. The results are presented in Table 2-17.

Table 2-17. Instrumental Variable (2SLS) Estimation of the Hog Price Equation

Variable	Parameter Estimate	Standard Error	t value	P value
Intercept	58.030	0.1440	402.92	<.0001
D_ma2	1.928	0.0539	35.79	<.0001
D_ma3	–0.167	0.0330	–5.06	<.0001
D_ma4	3.925	0.2377	16.51	<.0001
R1[a]	–10.710	0.0361	–296.50	<.0001
pfbin2	–29.705	0.3824	–77.69	<.0001
pfbin3	–5.939	0.1976	–30.06	<.0001
pfbin4	–7.888	0.1271	–62.07	<.0001
pfbin5	5.933	0.3383	17.54	<.0001
Loin-eye depth (mm)	0.000	0.0027	0.01	<.9955
Liveweight per head (lb)	–0.039	0.0006	–67.42	<.0001
Time	0.055	0.0001	492.39	<.0001
Time squared	–2.140	0.0121	–177.23	<.0001
Adjusted R^2	0.651			

[a] Regional binary variable R1=1 if region is East; R1=0, otherwise.

Accounting for the endogeneity of marketing arrangement portfolio choices produced a couple of interesting results. First, two coefficient estimates on the portfolio binary variables changed signs, such that now three out of four portfolio binary variables are negative. The signs on pfbin2 (marketing contracts), pfbin3 (cash/spot and marketing contracts), and pfbin4 (cash/spot, marketing contracts, and packer owned) are negative, meaning that all AMAs reduce the average price for live hogs relative to cash/spot procurement only. The only qualitatively different result is pfbin5 (marketing contracts, packer owned, and other), which is positive. This result is

[17] Plants provided the capacity measures in the transactions data collection or the pork packers' survey.

difficult to interpret because this portfolio includes “other,” the content of which is unknown. The portfolio’s other feature is that it does not include cash/spot market purchases. However, this may not be a decisive factor because pfbin2 does not include cash/spot purchases either, yet it is still associated with a lower average price relative to cash market purchases. The results show that packers that use of a combination of marketing arrangements, on average, pay lower prices for their hogs relative to plants that use the cash/spot market only.

The second interesting result comes from comparing the magnitudes of the portfolio effects with the magnitudes of the individual marketing arrangement effects. Take, for example, pfbin3 (cash/spot and marketing contracts) and compare it with d_ma2 (marketing contracts). The magnitude of the negative price effect of the portfolio ($58.03 – $5.94 = $52.09/cwt) is larger (i.e., the price is lower) than the sum of the individual marketing arrangement effects ($58.03 + $1.93 = $59.96/cwt). Furthermore, comparing the magnitude of the pfbin4 (cash/spot, marketing contracts, and packer owned) with the sum of d_ma2 (marketing contracts) and d_ma3 (packer owned), the effect of the portfolio ($58.03 – $7.89 = $50.14/cwt) is larger (price is lower) then the sum of individual effects ($58.03 + $1.93 – $0.17 = $59.79/cwt). The results appear to indicate that individual marketing arrangements have minimal additional effect on the average price (i.e., the portfolio system binary variables capture almost the entire effect on lowering the average price). As will be seen in Section 3, these results are supportive of the claim that the various marketing arrangements may be complementary to each other.

2.4 SHORT-RUN PRICE EFFECTS OF AMAs

MPR data from August 10, 2001, through September 30, 2005 (the period in which MPR was in effect) were used to estimate the impact of AMAs on spot or negotiated market prices.[18] The six types of marketing instruments are (1) negotiated purchases, (2) other market formula purchases (based on formula price other than the market for hogs, pork, or a pork product; formula may be based on one or more futures or options contracts), (3) hog or pork market formula purchases

[18] Aggregate quantity data were obtained by multiplying proportions of head in each category by average pork production per week.

(formula price based on market for hogs, pork, or a pork product), (4) other purchase arrangements (includes long-term contract agreements, fixed-price contracts, cost of production formulas), (5) packer sold (sold for slaughter to another packer), and (6) packer owned (hogs owned by a packer for at least 14 days before slaughter). Price data were available only for categories 1 through 5 because packer-owned hogs were not traded. Hogs owned by packers (5) was viewed as intermediate inputs and therefore not included in the empirical model. However, the price of packer-sold hogs was taken to be the imputed price of packer-owned hogs because this price is a measure of the opportunity cost of hogs owned by packers.

For the econometric analysis, all marketing arrangements (categories 2 through 4) were aggregated together. The quantity index was the Fisher Ideal index multiplied by the sample mean average of quantities for this category. We obtained the price index by dividing the total value of hogs slaughtered by the quantity index. Summary statistics of the three marketing arrangements used in the econometric analysis (i.e., negotiated, contracted, and packer owned) are shown in Table 2-18.

Table 2-18. Summary Statistics of MPR Weekly Swine Prices and Quantities, August 10, 2001–September 30, 2005

Variable	N	Mean	Standard Deviation
Negotiated price	217	59.4053610	12.1348986
Contract price	217	60.3493519	9.7093267
Packer owned price	217	63.1364716	11.8053015
Negotiated pounds	217	50.4345681	8.6589549
Contract pounds	217	257.7430445	21.3350240
Packer owned pounds	217	72.8061901	8.6881661

Note: prices are in $/cwt, and quantities are in 1,000 lbs. carcass weight.

The different data were initially analyzed to determine their time-series properties. Dickey-Fuller tests indicated unit roots in all six data series. Thus, cointegration between the variables in the models estimated had to be established to ensure the error terms were stationary so that the statistical results could be viewed as valid.

The relationship between the cash/spot or negotiated price and AMAs was postulated to result from the effects of packer decisions regarding the purchase of hogs for slaughtering and processing. Packers were expected to select a portfolio of hogs purchased from different marketing arrangements (cash/spot market, contracts, and packer owned) to maximize net revenue from slaughtering and processing. Given anticipated demand for pork, packers would then choose the mix of hogs to minimize costs. From week to week, quantities of hogs available for slaughtering are predetermined (i.e., the quantities available are determined by decisions made in previous weeks) (Bullock, 2003). This means that the market within the week determines the cash/spot price for hogs, given the quantities of hogs offered for sale on the cash/spot market, hogs available from contracting, and hogs available from packer-owned operations. Therefore, causality is seen as running from the quantities of hogs sold from the various sources (cash/spot, contract, and packer owned) to cash/spot price for hogs within the week. Because anticipated demand for pork changes from week to week, expected quantity of pork to be processed is also a determinant of the inverse demand function for negotiated hogs.

To estimate the effect of AMAs on the cash/spot price, we added quantities of primal pork cuts sold in each week to the data set. We constructed an index of quantities to enable measurement of the effect of demand for pork on demand for hogs by packers within the week. The data were obtained from USDA/AMS, National Carlot Meat Trade Review: Meat, Livestock, and Slaughter Data, 2001–2005. The proportions of each cut (loin, butt, ham, picnic, belly, rib) were multiplied by average weekly U.S. pork production to obtain thousands of pounds marketed. Table 2-19 provides a summary of these data. We constructed a Fisher Ideal index of the quantities, multiplying the index by the average sample quantity of pork produced.

Appendix B of Volume 4 specifies how the model was formulated for econometric analysis. In essence, we used dynamic seemingly unrelated regression (DSUR) to estimate the three inverse demand functions for marketing instruments (cash/spot, contract, and packer owned). In addition to the current weekly quantities of hogs from cash/spot, contract, and company sales, as well as the current weekly quantity of pork

Table 2-19. Summary Statistics of MPR Pork Primal Cut Slaughter Values and Quantities, August 10, 2001–September 30, 2005

Variable	N	Mean	Std Dev
Loin price	217	79.9664516	10.1727399
Butt price	217	59.2835945	12.5855802
Ham price	217	50.3645161	12.2033613
Rib price	217	122.0556682	17.1121195
Belly price	217	83.9891705	14.4318368
Picnic price	217	40.8767281	11.1189015
Loin pounds	217	110.3752063	30.6538388
Butt pounds	217	58.3497952	18.3915121
Ham pounds	217	94.3521645	26.9974187
Rib pounds	217	12.5418756	6.9529211
Belly pounds	217	21.7612271	14.2663447
Picnic pounds	217	29.5053996	10.0565297

Note: Values are in $/cwt, and quantities are in 1,000 lbs carcass weight.

sold, the model also includes first differences in lags and leads for 3 weeks for all four variables. In addition, 11 monthly binary variables and an intercept were included in the equations to account for any seasonal effects that may be present in demand. Finally, a linear time-trend variable was included to account for omitted variables like wage rate in meat slaughtering. Such data were unavailable on a weekly basis and could not be included in the analysis.

The estimation procedure was conducted in two stages. In the first stage, the three prices (cash/spot, contract, and packer owned), the quantities of the three hog types, and the index of pork quantity were regressed on the first differences in lags and leads of quantities of hogs, the index of pork quantity, the time trend, the intercept, and the 11 binary variables. The residuals from the first-stage estimates were then used to form a system of equations to estimate the model using the iterated seemingly unrelated regression method. In the second stage, the residuals were corrected for first-order autocorrelation. Two different sets of estimates were obtained: one set for which symmetry was imposed on the cross-quantity variables of hogs and one set for which both symmetry and the restriction of negative semidefiniteness of the matrix of hog quantities was imposed. Theory suggests that both restrictions should hold. The latter restriction was imposed to ensure that the cost function had the right curvature conditions for the economic analysis. The advantage of the DSUR approach is that both endogeneity and dynamics are accounted for in a rather general way.[19] The results also allow us to evaluate the relationship between the steady-state values of the variables of interest. In addition, the relationships estimated were found to be cointegrated with stationary error terms so that valid inferences can be made from the estimation results.

Given these econometric considerations, the estimated relationship between the cash/spot price, quantities of hogs sold, and index of quantity of pork processed is as follows:[20]

$$\hat{pneg}_t = \underset{(0.051)}{-0.285}\, qneg_t \; \underset{(0.036)}{-0.172}\, qcon_t \; \underset{(0.050)}{-0.198}\, qown_t \; \underset{(0.040)}{+0.097}\, qpork_t \quad . \qquad (2.2)$$

where neg refers to cash/spot sales, con refers to contract sales, and own refers to packer owned sales. All the quantity variables are highly statistically significant, as indicated by the asymptotic t-values constructed by forming the ratio of each coefficient estimate to its standard error (value in parenthesis). As indicated by the signs of the quantity variables, increases in quantities of cash/spot, contract, and packer-owned hogs all depress the cash/spot price of hogs. Greater anticipated demand for hogs, as indicated by the positive sign on the $qpork_t$ variable, leads to an increase in demand for hogs sold on the cash/spot market, and therefore the cash/spot price of hogs, everything else equal.

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[19] For example, one might expect that inventory holding is important from week to week, so the response of hog prices should be a distributed lag to current and past hog quantities and to current and past pork quantities. By including first differences in three lags of these variables, we are in essence including four lagged variables on each right-hand side variable and should therefore account for any dynamics that might be present. Including first differences in leads and lags also accounts for nonstrict exogeneity and endogeneities in the regressors that might be present in the model.

[20] These estimates are from Table B-6 in Appendix B of Volume 4. The estimates are for symmetry and negative-semidefiniteness imposed. The results are very similar to the case where negative-semidefiniteness is not imposed. Therefore, only these results are reported.

Of particular interest in Eq. (2.2) is the effect of both contract and packer-owned hog supplies on the cash/spot price. As anticipated, these effects are negative—an increase in either contracted hogs or packer-owned hog sales decreases the cash/spot price of hogs. At the sample means, a 1% increase in contract hogs sold causes the spot price to decline by 0.75%. A 1% increase in packer-owned hogs sold causes the cash/spot price to decline by 0.24%.

The negative relationship between the two AMAs and cash/spot price occurs, at least in part, because the three types of hogs are substitutes for one another in pork production. A higher quantity of either contract or packer-owned hogs available for sale lowers the prices of contract or packer-owned hogs and induces the packer to purchase more of the now relatively less expensive hogs and purchase fewer hogs sold on the cash/spot market.

Eq. (2.2), also as anticipated, shows that the demand curve for hogs is negatively sloped. A 1% increase in quantity of hogs sold on the cash/spot market decreases the cash/spot price by 0.24%, everything else held constant.

The estimated Eq. (2.2) does not allow for adjustment of pork quantities to changes in hogs slaughtered. Clearly, full equilibrium adjustment to changes in quantities of contract supplies and packer owned supplies would require the quantities of pork and prices of pork to change as both processors and consumers respond to the market changes. The packer model of input demand functions was combined with the packer model of price equations for the six primal pork cuts, as well as demand for the six primal pork cuts to calculate, the full impact of changes in spot market supplies, contract supplies, and packer owned supplies.[21] These total elasticities were calculated as follows: (1) a 1% increase in cash/spot market quantities causes the cash/spot market price to decrease by 0.27%, (2) a 1% increase in contract hog quantities causes the cash/spot market price to decline by 0.88%, and (3) a 1% increase in packer-owned hog quantities causes the cash/spot market price to decline by 0.28%. These estimates are quite

[21] In the economic literature, these estimated effects are for "industry-derived demand," while the effects of changes in input quantities on input price indicated by Eq. (2.2) are for "output-constant input demand."

close to the estimates derived from Eq. (2.2) of 0.24, 0.75, and 0.24, respectively, suggesting the downstream effects from changes in hog supplies are very small compared with the substitution effects among different sources of hogs for slaughter.

In addition to the above analyses, another model was estimated to evaluate how the spread between the cash/spot price and AMA supplies (referring to all marketing arrangements other than cash or spot markets) prices changes as the proportion of AMA supplies increases. We examine this relationship to see if in fact an increase in market power creates more of a gap between prices on the different market outlets. The same data set was used for estimation but with contract and packer-owned hog quantities aggregated into an index. We used the same procedure shown in Eq. (2.2). That is, the dependent variable, cash/spot price, and each of the right-hand side variables were first regressed on an intercept, 11 monthly binary variables, a time trend, three first differences in leads and lags of the current weekly price of AMA supplies (pama), and the ratio of AMA supplies to negotiated (cash/spot) market supplies (qama/qneg). In the second stage, the residuals on the dependent variable were regressed on the residuals of pama and (qama/qneg) to obtain the dynamic ordinary least squares (DOLS) estimates. To account for serial correlation in the residuals, DOLS estimates were obtained with correction for first-order autocorrelation in the residuals. The results were as follows:

$$\underset{}{\mathrm{pn\hat{e}g}_t} = \underset{(0.68)}{-13.61} + \underset{(0.01)}{1.23}\ \mathrm{pama}_t - \underset{(0.05)}{0.27}\ (\mathrm{qama}/\mathrm{qneg})_t \tag{2.3}$$

$$\overline{R}^2 = 0.99 \quad \hat{\rho} = \underset{(0.05)}{0.70}$$

where, as before, values in parentheses are standard errors of the parameters, $\hat{\rho}$ is the estimated first-order autocorrelation coefficient, and $\overline{R}^2$ is the adjusted R-squared value. The results show that both variables are highly statistically significant. Also, the results confirm the hypothesis that increases in AMA supplies relative to negotiated supplies decreases the cash/spot price, given the current level of the price of AMA supplies. Therefore, the gap between the cash/spot market price and the

AMA supplies price widens as the proportion of supplies through AMAs increases.

While the results in this section establish a negative relationship between AMA supplies and the cash/spot market price for hogs, this relationship does not necessarily imply that hog producers selling on the cash/spot market would be better off restricting or reducing AMA supplies. If reductions in supplies of hogs sold for contract or owned by packers are reduced through regulation, at least a portion of that reduction in supplies would be diverted to the cash/spot market, causing an offsetting decline in the cash/spot market price. A complete analysis of the effects of restricting use of AMAs on hog prices and hog producers is given in Section 6 of Volume 4.

2.5 PRICE DISPERSION IN THE SPOT MARKET FOR LIVE HOGS

In this section, we examine the phenomenon of price dispersion in the cash/spot market for live hogs. The empirical puzzle of price dispersion of homogenous goods has been noticed in the various markets. This literature that originates with the seminal paper by Stigler (1961) has been thoroughly surveyed by Baye, Morgan and Scholten (2005). Almost all previous studies focused on the consumer goods market, so this is a first attempt to examine this phenomenon in an intermediate good market. We present the empirical evidence and discuss and test several possible explanations for what we observe based on industrial organization theory.

2.5.1 Empirical Evidence

The data preparation procedure was similar to the procedure described in Section 2.1.2 with a few minor differences. First, we only focused on hogs transacted through direct trade between a farmer and a packer. According to Table 2-3, this type of transaction accounted for about 8.9% of the total transactions during the sample period. Second, we did not exclude transactions with five or fewer market hogs because we wanted to examine the entire price dispersion in this market. Third, we excluded all transactions for which the total number of hogs was greater than the number of barrows and gilts. These are the transactions for which nonmarket hogs like sows and boars are also included in the lot. Fourth, prices are expressed in dollars per 100 pounds of live hog weight instead of carcass weight. We also eliminated prices that are outside the $20 to $100 range. After conducting these four screening procedures and the procedures explained in Section 2.1.2, we ended up with 270,785 lots with a total of 17,609,568 hogs. The data originate from 23 plants owned by 12 companies. These numbers are slightly larger than those reported in the column of direct trade in Table 2-3, reflecting the fact that we included transactions with five or fewer hogs.

To conduct the regression analyses below, we needed to further prepare the data. We dropped all the observations that were missing information on quality measures (lean percentage, back fat, and loin-eye depth) and the location (three-digit zip code) of the seller. Furthermore, we dropped all observations that have values less than 10 millimeters on the loin-eye depth. Finally, the working data set has 183,665 transacted lots with a total of 12,236,418 hogs for 18 plants owned by eight companies.

Table 2-20 provides the summary statistics of the working data set. On average, each lot contains about 67 hogs, with the range from 1 hog to 394 hogs. The average transaction price for the sample period is about $58 per cwt of liveweight. The average lean percentage is about 53%. The average back fat is around 20 mm, and the average loin-eye depth is around 57 mm. Notice that the standard deviations for the three quality measures are pretty small compared with their means, indicating there is not much variation in quality among the transacted hogs. The average of the carcass weight of the lots is around 193 pounds. Finally, the variable ratio is the number of low-quality hogs as a percentage of the whole lot. The number of low-quality hogs is defined as the sum of the number of off-quality hogs, the number of assessed sort loss hogs, and the number of condemned hogs in the lot. On average, each lot contains about 1.78% off-quality hogs.

The first impression about the magnitude of the price dispersion can be obtained from the daily means, ranges, and standard deviations of transaction prices. Transactions occurred on 644 days in the data set. Table 2-21 reports the summary statistics. On average, each day, the price range (defined as the maximum price minus the minimum price) is around $24. This accounts for about 40% of the mean of the transaction prices. The maximum range in 1 day’s transaction price can be as high as $61. The statistics on the standard deviation gives roughly the same information, indicating strong price dispersion.

Table 2-20. Summary Statistics of the Working Data Set

Variable	Definition	Mean	St. Dev.	Min	Max
Q	Number of heads in the lot	66.6236	63.1421	1.0000	394.0000
P	Transaction price of the lot	57.7008	12.4348	20.5681	98.4584
Lp	Average lean percentage of the lot	52.8985	2.2953	1.0000	66.0000
Bf	Average back fat of the lot	19.7682	3.8291	2.0000	57.9120
Led	Average loin-eye depth of the lot	57.2453	6.0892	11.0000	100.8380
W	Average carcass weight of the lot	192.9760	13.2470	150.0000	220.0000
Ratio	The ratio of low-quality hogs in the lot	0.0178	0.0771	0.0000	1.0000

Table 2-21. Measures of Price Dispersion[a]

Variable	Mean	St. Dev.	Min	Max
Mean	59.4034	11.9641	36.9508	83.7075
Range	23.8500	8.6323	0.5515	61.1752
Standard deviation	3.7487	1.0979	0.3106	7.7339

[a] The number of observations here is 644.

To make these statistics independent of the absolute price level, we calculated two other price dispersion measures: the range/mean ratio and the standard deviation/mean ratio (coefficient variation) of the transaction prices for each day. This calculation allows us to compare the price dispersion across different trading days. In Figure 2-2, we plot the range/mean ratio. The graph indicates that the dispersion has a few spikes; however, most of the time, the measure is around 0.4, signaling a consistent rather than sporadic presence of dispersion in the live hog price data. Figure 2-3, where we plot the coefficient of variation, shows a similar pattern of price dispersion in this market.

Figure 2-2. Time-Series Plots of the Range/Mean Series

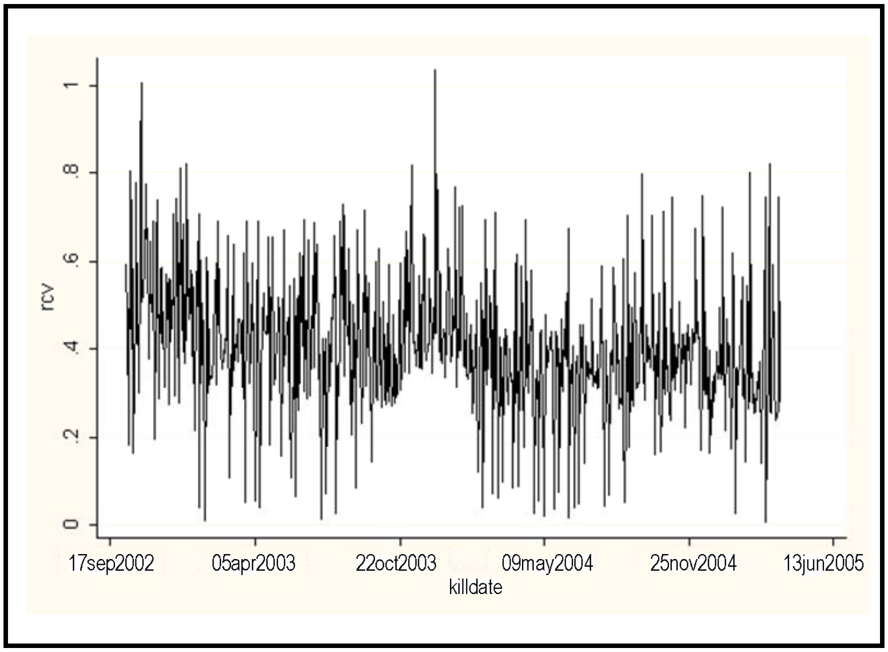
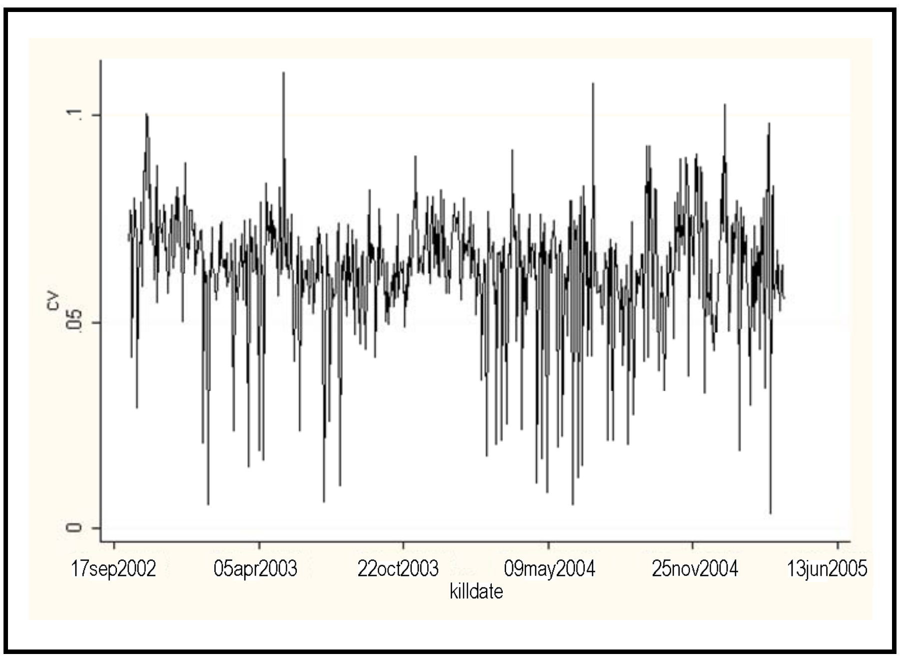


Figure 2-3. Time-Series Plots of the Coefficient Variation Series



2.5.2 Possible Explanations

What causes the price dispersion in the live hogs market? Several competing hypotheses may explain what we observe. Because of the computational intensity of some of the employed techniques, we focused on transactions that involve only sellers in the state of Iowa.[22]

As a base reference, we first regressed the ratio between the individual lot transaction price and the mean of transaction prices for that day on the constant, the plant binary variables, and the transaction day binary variables. Table 2-22 reports the regression results. Statistics for the binary variables were omitted; we focused only on the adjusted R^2 of 0.1004. This tells use that the plant and transaction day binary variables can only account for about 10% of the variation in price.

Table 2-22. OLS Regression Results with Binary Variables

Variable	Estimate	t-stat
Constant	0.9382	180.29
Adjusted R^2	0.1004	

Some of the explanations for the observed price dispersion are as investigated below.

Quality Differences

An obvious first explanation for price dispersion is the quality variation. We examined the importance of quality differences in determining the price dispersion by expanding the list of independent variables used in the previous regression. Independent variables now include the constant, the three quality measures, the weight variable, the ratio of bad hogs, and the plant and transaction day binary variables. Table 2-23 reports the regression results. Statistics for the binary variables were omitted. All coefficients have expected signs. Average lean percentage, average loin-eye depth, and average weight have significant positive effects on the transaction price. The average back fat and the ratio of bad hogs have significant negative effects on the transaction price. The adjusted R^2 increased to 0.2022.

[22] The number of observations is 50,115.

Table 2-23. OLS Regression Results with Quality Measures

Variable	Estimate	t-stat
Constant	0.7276	57.54
Lean percentage	0.0033	15.86
Back fat	–0.0030	–26.86
Average loin-eye depth	0.0009	10.74
Average weight	0.0001	5.87
Ratio	–0.1725	–30.21
Adjusted R^2	0.2022	

Transportation Costs

The second possible explanation for the price dispersion is the transportation costs. If a packer needs to pay more to transport the hogs from the farmer to the packing plant, it will pay a lower price to farmers who are located further away from the processing plant. To examine the explanatory power of this hypothesis, we calculated the distance measure for each transaction. For each transaction, we observed the three-digit zip code of the seller and the city of the buying plant. Using a zip code atlas, we located the center town of each three-digit zip code area and then obtained the shortest driving distance between the center of town of the seller's zip code and the city of the buying plant using Mapquest. Because hogs are always transported by trucks, the driving distance is the most appropriate distance measure. The mean of the driving distance for these transactions is 113.29 miles. The standard deviation is 96.11 miles.

We included the distance measure in our regression in Table 2-24. As expected, the distance measure has a significant negative effect on the transaction price. However, the magnitude of this effect is very small. Including the distance measure leaves other coefficients almost unchanged and only boosts is the adjusted R^2 by 0.0002. The conclusion is that transportation costs do not contribute to the price dispersion we observe in this market.

Table 2-24. OLS Regression Results with Distance Measure

Variable	Estimate	t-stat
Constant	0.7293	57.64
Lean percentage	0.0033	15.77
Back fat	–0.0030	–26.87
Average loin-eye depth	0.0009	10.86
Average weight	0.0001	5.80
Ratio	–0.1714	–29.97
Distance	–0.0000	–3.07
Adjusted R^2	0.2024	

Search Costs

The basic idea of the search costs theory adapted to the cash/spot market for live hogs is the following. Farmers need to incur a positive search cost to search for the best price to sell their hogs. Naturally, farmers with high search costs (or low search benefits) are less likely to search, and farmers with low search costs (or high search benefits) are more likely to search. A farmer who searches more is more likely to obtain a high price because the expected highest price increases with the number of searches. In equilibrium, different packers will offer different prices and some farmers get high prices and some farmers get low prices.

An implication of the search models is that for lots having more hogs farmers should have a higher incentive to search because the potential benefits of searching are higher than for lots with a small number of hogs. As they search more, farmers with bigger lots should receive, on average, higher prices.[23] To test for this hypothesis, we include the lot size variable into our regression. The average lot for Iowa sellers has 61.75 hogs, with the standard deviation of 59.56 hogs. As Table 2-25 shows, the estimated coefficient for the lot size is positive and significant, and the adjusted R^2 increases to 0.2532. This result lends support to the search costs explanation. Roughly 5% of the variation in the transaction prices can be attributed to farmers' search behavior.

[23] Sorensen (2000) tests another implication of the same theory using data on prescription drugs, that is, prices are less dispersed for those drugs where consumers' potential benefits of search are high.

Table 2-25. OLS Regression Results with Lot Size

Variable	Estimate	t-stat
Constant	0.7293	57.64
Lean percentage	0.0026	12.67
Back fat	–0.0025	–23.35
Average loin-eye depth	0.0010	12.62
Average weight	–0.0001	–2.21
Ratio	–0.1860	–33.58
Distance	–0.0000	–12.38
Lot size	0.0002	58.01
Adjusted R^2	0.2532	

The obtained results have two caveats. First, it is possible that bigger lots are more difficult to sell; hence, packers may offer a lower price to farmers with bigger lots. If this is the case, then the estimated effect of searching is underestimated because the lot size affects the transaction price in the opposite direction. Second, the lot size is a quantity measure, and the dependent variable of our regression analyses is the price. It is possible that the quantity measure in the regression is endogenous and the results are then biased. Both of those caveats need further investigation.

Competition Intensity

Yet another explanation for the observed price dispersion is the competition intensity that differs in different areas. In some areas, many farmers compete against each other to sell their hogs, and packers may be able to take advantage of it and depress the prices. To control for this effect and to test this proposition, we include in the regression analysis the binary variable for each seller's zip code. As shown by the results in Table 2-26, including these additional binary variables further boosts the adjusted R^2 by 1.37%, indicating that the explanatory power of this variable is also limited. Also notice that the weight variable and the distance variable change signs, but their t-stats, although significant, are rather small, given the sample size.

Table 2-26. OLS Regression with Competition Intensity

Variable	Estimate	t-stat
Constant	0.7731	62.70
Lean percentage	0.0026	12.76
Back fat	–0.0023	–22.01
Average loin-eye depth	0.0009	11.68
Average weight	–0.0001	–2.30
Ratio	–0.1818	–32.64
Distance	0.0000	6.97
Lot size	0.0002	54.88
Adjusted R^2	0.2669	

The list of possible explanation for why we observe significant price dispersion on the spot market for live hogs is not exhausted. Several other competing hypotheses can be added, such as price discrimination (first degree or third degree) and the role of committed procurement (the latter is investigated elsewhere in this report). Although we were able to cast some light onto possible drivers of price dispersion, the significant portion of the unexplained variability in spot prices still remains an unsolved puzzle.

2.6 SUMMARY

In this section, we examined the behavior of market hogs' prices and quantities. We focused on the finished hog market segment between producers/farmers and packers. The data come from three sources: surveys of hog producers and packers and transaction data from large packers. The data reported in the producers' survey reflect their selling practices and the data from the packers' survey and individual transactions data both reflect packers' buying practices. Due to inconsistencies in and across these data sources; secondary, publicly available, data sources were also utilized to conduct the analyses presented in the next sections.

The main conclusion of this section is that AMAs are becoming an integral part of producers' selling practices and packers' procurement practices. There are also significant regional differences in the observed patterns of use of marketing arrangements with a stronger reliance on cash/spot markets in the Midwest than in the East. The detected differences in carcass prices that packers pay for their hogs are significant, some of which can be explained by factors such as region, quality, or plant size. However, even after controlling for those factors, the remaining differences need to be explained by based on organizational issues related to supply chain management in the livestock processing sector. Results seem to indicate that plants that use a combination of marketing arrangements on average pay lower prices for their hogs relative to plants that use the cash/spot market only. The second interesting result comes from comparing the magnitudes of the portfolio effects with the magnitudes of the individual marketing arrangement effects. The results appear to indicate that individual marketing arrangements have minimal additional effect on the average price (i.e., the portfolio system binary variables capture almost the entire effect on lowering the average price).

Of particular interest for this study is the effect of both contract and packer-owned hog supplies on the cash/spot price. As anticipated, these effects are negative. That is, an increase in either contracted hogs or packer-owned hog sales decreases the cash/spot price of hogs. The elasticities of industry derived demand are quite close to the estimates derived from output-constant input demands, suggesting that downstream effects from changes in hog supplies are very small compared with the substitution effects among different sources of hogs for slaughter. A higher quantity of either contract or packer-owned hogs available for sale lowers the prices of contract or packer-owned hogs and induces the packer to purchase more of the now relatively less expensive hogs and purchase fewer hogs sold on the cash/spot market.

Finally, we conducted an analysis to enhance our understanding about mechanisms that may explain significant price dispersion in the cash/spot market for live hogs. On average, the live hog price range (defined as the maximum price minus the minimum price) is approximately $24/cwt each day. This accounts for about 40% of the average transaction price. Based on our analysis, we are able to partially explain this phenomenon using quality, transportation costs, search costs, and competition intensity differences, but a large proportion of the total variation in price still remains unexplained and requires further research.

3 Economies of Scale, Cost Differences, and Efficiency Differences Associated with Alternative Marketing Arrangements

In this section we estimate the cost differences and the economies of scale in pork packing and analyze the degree to which those differences can be explained by the differences in AMAs that different plants use to procure their hogs. We also look at the efficiency differences across plants by analyzing whether the observed profitability differences can be explained by the packers' AMA portfolio choices. In addition, we test for the presence of statistically significant complementarities across AMAs as an explanation for the differences in observed profitability across plants.

3.1 IDENTIFYING AND MEASURING COST AND EFFICIENCY DIFFERENCES

The first difficulty presented in identifying cost and efficiency differences is separating any market power effects from purely cost changes associated with changes in marketing arrangements. This requires development of an econometric model where an attempt is made to identify and estimate the separate effects of market power and marketing arrangements on prices and price-cost margins.[1] One approach taken in this study is to use the monthly farm–wholesale price spread data published by USDA, ERS to estimate a monthly model showing the relationship between the price spread and various variables believed to be important in causing changes over time in the price spread. The second approach relies on the individual transactions data from large packers to estimate a structural model to test whether market power exists and whether the source of that market power could be related to marketing arrangements in procuring market hogs.

3.1.1 Industry-Level Data Approach

The particular model estimated, which is described in more detail in Appendix B Attachment 2, has the following form:

$$\left(\frac{P}{W_1}\right)_t = b_0 + b_1 amashare_t + (c_0 + c_1 amashare_t)\left(\frac{W_{FIt}}{W_{1t}}\right)^2 + (d_0 + d_1 amashare_t)\left(\frac{W_{FIt}}{W_{1t}}\right)Y_t + u_t \ , \tag{3.1}$$

where the dependent variable is the wholesale price (P) to farm price (W_1) ratio. (Both prices are expressed in units of the wholesale product, price per pound wholesale weight.) The variable a*mashare* is the share of supplies of hogs through AMAs in total hog production (which refers to the sum of contract and packer-owned hogs in this section), W_{FI} is an index (Fisher Ideal) of wage rates for slaughtering and energy prices, Y is production of pork, and u is an error term. The theoretical basis of this equation is based on the framework of Schroeter (1988). The form of the particular equation in Eq. (3.1) is new to the literature and is based on a quadratic cost function, which seems to fit the circumstances of the industry quite well. The first two terms on the right-hand side of the equation (i.e., the intercept and term involving *amashare*) can represent the effect of any market power that may arise from either market power in the output market for pork, the input market for hogs, or a combination of the two markets. Notice that *amashare* can have an influence on market power. Also notice that *amashare* interacts with both

[1] It needs to be stressed that the disaggregate model used for the simulation analysis in Section 6 does account for changes in imperfect competition. However, the equations estimated contain both market power and differential cost effects from the AMAs, so additional analysis is required to separate the source of change.

the index of marketing prices and the output in costs. By interacting this variable with terms in the cost function, we are able to measure and test how cost economies and efficiencies vary by AMA.[2]

As in the other econometric analyses conducted, unit roots were found to be present, so we used Phillips and Loretan's (1991) method of dynamic ordinary least squares (DOLS) to estimate the parameters. This means that first differences in lags and leads of the right-hand side variables were included as explanatory variables in the model to purge the model of transient dynamics and any endogeneity effects. Initially, monthly binary variables were also included in the model, but the variables were deleted after they were not found to be statistically significant as a group. Also, the intercept was found to be very insignificant and was dropped.[3]

The estimated equation was as follows:

$$\left(\frac{\hat{P}}{W_1}\right)_t = \underset{(0.0406)}{1.278235}\, amashare_t - \underset{(14888.8)}{21806.8}\left(\frac{W_{FI}^2}{W_1^2}\right)_t + \underset{(17138.9)}{27004.8}\; amashare_t\left(\frac{W_{FI}^2}{W_1^2}\right)_t$$

$$+\underset{(0.1153)}{0.348274}\left(\frac{W_{FI}^2}{W_1^2}\right)_t Y_t - \underset{(0.1324)}{0.3956}\, amashare_t\left(\frac{W_{FI}^2}{W_1^2}\right)_t Y_t$$

$$+\underset{(8887.1)}{19220.8}\,\Delta\left[\left(\frac{W_{FI}^2}{W_1^2}\right)_t\right] - \underset{(10266.9)}{22217.7}\,\Delta\left[amashare_t\left(\frac{W_{FI}^2}{W_1^2}\right)_t\right]$$

$$-\underset{(0.0708)}{0.23965}\,\Delta\left[\left(\frac{W_{FI}^2}{W_1^2}\right)_t Y_t\right] + \underset{(0.0814)}{0.273775}\,\Delta\left[amashare_t\left(\frac{W_{FI}^2}{W_1^2}\right)_t Y_t\right] \tag{3.2}$$

$$R^2 = 0.9668$$

$$\hat{\rho} = \underset{(0.1345)}{0.622802},$$

[2] Initially, we attempted to separate contract share from packer owned share in the model, but this separation led to extreme multicollinearity that affected any ability to separate AMAs from other variables in the model.

[3] In addition, as a group, the first differences in leads were not found to be significant nor did exclusion of these variables affect the parameter estimates in any major way. Thus, the first differences in leads also were deleted from the model.

where $\hat{\rho}$ is the estimated standard error of the first-order autocorrelation parameter. Values in parentheses are estimated standard errors of the parameters of the model.

As indicated, the AMA supplies variable (*amashare*) has a positive and significant effect on market power (i.e., the first term in Eq. [3.2]), as anticipated. A higher proportion of AMA supplies leads to an increase in market power. At the sample means (August 2001 through September 2005), the average markup/markdown is 1.10814, with a standard error of 0.035196. For the null hypothesis of price-taking behavior (coefficient estimate equal to one), the t-value is 3.07146. Therefore, we strongly reject price-taking behavior, although the degree of market power is quite modest.[4][5]

The other terms in the first and second rows of the model (other than the estimated first term on the right-hand side of Eq. [3.2]) provide an estimate of the effect of marginal processing costs on the wholesale–farm price ratio of pork. The marginal effect of a change in output (Y) on the price ratio is 7.36302×10^{-5}. In elasticity form, a 1% increase in output at the sample means is estimated to increase marginal costs by 0.04%. This estimate is not statistically significantly different from zero at the sample means, suggesting that the average packer in the industry operated very nearly at the point of constant returns to scale. However, this relationship is not independent of AMAs. In particular, for each 1% increase in AMA supplies, marginal costs with respect to output decline by 0.00148%, with a standard error of 0.000495. This implies a t-value of –2.98, indicating a significant economies of scale effect from increases in the share of AMA supplies.

The effects of changes in AMAs on market power and marginal processing costs can be identified and measured separately from Eq. (3.2). The estimated covariances of the parameter estimates, together with the parameter estimates of Eq. (3.2), were used to estimate the effect of AMA supplies on market

[4] We also expect this estimate to be an upper-bound value for market power, based on the analysis of Wohlgenant (2001), because of the assumption that packers cannot alter the proportion of hogs in relationship to marketing inputs in response to changes in the price of hogs.

[5] We consider this market power estimate to be modest in the sense that many studies have found markups of 20% or more in other industries (see, for example, Bhuyan and Lopez [1997]).

power, the effect on marginal costs, and the net effect on the price ratio. Put in terms of elasticities, a 1% increase in AMA supplies share leads to a 0.735% increase in market power, with a standard error of 0.020, holding marginal costs constant. A 1% increase in AMA supplies leads to a –4.99% change in marginal costs, with a standard error of –1.67, holding the degree of market power constant. The net effect of market power and efficiency gains from increased AMA supplies is –1.47%, with a standard error of –0.40 for each 1% increase in AMA supplies. Thus, the benefits from increased AMA supplies outweigh increases in market power through decreased cost in procuring and processing pork. This means that reducing AMA supplies would have a net effect of increasing, not decreasing, costs of procuring and processing pork. This finding is consistent with the simulation results in Section 6, pointing to losses to producers from policies aimed at restricting the share of AMA supplies.

3.1.2 Packers' Individual Transactions Data Approach

In this approach we use structural econometrics to formally test whether the use of AMAs is the source of market power in the pork packing industry. We extend Schroeter's (1988) beef packing industry model and specify the packers' conjectures of the change in market output with respect to their own outputs as explicit functions of their own AMA supply stocks and the stocks of their competitors. Testing whether these stocks are significant determinants of the packers' equilibrium conjectures can be taken as a test on whether the use of the AMAs is a source of market power in this industry. The test is carried out using the firm-level individual transactions data, which enables us to relax the restrictive assumption that all firms have the same conjectural elasticities that has been regularly employed in all market power studies that rely on the aggregated industry-level data.

The Model

We modeled the industry as comprising N firms (packers) producing a homogenous output (pork) using a single homogenous material input (live hogs). Following Schroeter (1988), Azzam (1997), and other economics literature on meat packing, we assumed a fixed proportion production technology. As a result, with an appropriately chosen scale of prices, the quantities of the material input and the output can be represented by the same variable q^i, where (i =1,...,N). Packers compete against each other by setting the output quantities. We assumed that there are only two procurement channels: the cash or spot market, q_1, and the AMA supply channel, q_2, where the latter includes marketing contracts, production contracts, and packer-owned hogs. The main characteristic of the AMA supply channel is that when packers come to the spot market to buy live hogs, the AMA supply hogs are already fixed as the packers' stocks. The principal reason for this is the fact that AMA supplies represent packers' long-term supply chain management decisions where some of those contracts are written for 5 to 10 years, whereas our individual transactions data cover only 2.5 years.

Each time period t, given the stock of hogs q^i_{2t} from the AMA supply channel, packer i decides on how many hogs to procure through the cash channel (q^i_{1t}) and then converts all the hogs to pork and sells the pork in the downstream market. Therefore, packer i's payoff in period t is given by

$$\pi^i_t = W_t\left(q^i_{1t} + q^i_{2t}\right) - P_{1t}q^i_{1t} - P_{2t}q^i_{2t} - C_p\left(q^i_{1t} + q^i_{2t}\right), \qquad (3.3)$$

where W_t is the price of pork, $P_{1t}q^i_{1t}$ is the payment to the live hog suppliers through the spot channel, $P_{2t}q^i_{2t}$ is the payment to the live hog suppliers through the AMA supply channel, and $C_p\left(q^i_{1t} + q^i_{2t}\right)$ is packer i's production costs. Although q^i_{2t} is the packers' long-term decisions and is taken as given, the price P_{2t} will be determined in period t. This captures the fact that many marketing contracts use formula pricing where the contract price is linked to the current period spot price P_{1t}.[6]

To complete the model, we need to specify the cost function, the downstream inverse demand function for pork, the upstream inverse supply function for live hogs through the spot channel, and the rule for determining the price of live hogs in the AMA supply channel. Following Porter (1983), we specify the cost functions as

$$C_p\left(q^i_{1t} + q^i_{2t}\right) = \left[\theta_1 + \frac{1}{2}\theta_2\left(q^i_{1t} + q^i_{2t}\right)\right]\left(q^i_{1t} + q^i_{2t}\right) + F, \qquad (3.4)$$

[6] An example of this type of pricing, called "top-of-the-market clause" used in the beef sector, is found in Xia and Sexton (2004).

where the first part of C_p reflects the fact that the cost function is convex in quantities, and F represents the fixed cost. The inverse demand function for pork is given by

$$\log W_t = \gamma_0 + \eta \log(Q_t) + \gamma_1 \log p_{bt} + \gamma_2 \log p_{ct} + e_{dt}, \quad (3.5)$$

where Q_t is the total number of hogs that N packers procure through all the channels, that is, $Q_t = \sum_{i=1}^{N} (q_{1t}^i + q_{2t}^i)$; p_{bt} and p_{ct} are the prices for beef and poultry, the two main substitutes for pork; and e_{dt} is a shock with the property that $E(e_{dt}) = 0$. η represents the inverse demand elasticity for pork. The inverse supply function for live hogs through the cash channel is given by

$$\log P_{1t} = \delta_0 + \varepsilon \log(Q_{1t}) + \delta_1 \log p_{wt} + \delta_2 \log p_{et} + e_{1t}, \quad (3.6)$$

where Q_{1t} is the total number of hogs that N packers procure through the cash channel, that is, $Q_{1t} = \sum_{i=1}^{N} q_{1t}^i$; p_{wt} and p_{et} are the wages of production workers and the price of energy, which approximate input costs in the production of live hogs; e_{1t} is a shock with the property that $E(e_{1t}) = 0$; and ε is the inverse supply elasticity for live hogs through the cash channel. Finally, the rule for determining the price of live hogs in the AMA supply channel is approximated as

$$\log P_{2t} = \lambda_0 + \mu \log(P_{1t}) + e_{2t}, \quad (3.7)$$

where e_{2t} is a shock with the property that $E(e_{2t}) = 0$.

In every period, given its own stock of hogs through the AMA supply channel and the stocks of other packers, q_{2t}^i ($I = 1,\ldots,N$), packer i chooses q_{1t}^i to maximize its current period profit π_t^i. Using Eq. (3.3) and Eq. (3.4), the first-order condition for profit maximization is as follows:

$$0 = \frac{\partial \pi_t^i}{\partial q_{1t}^i} = \frac{\partial W_t}{\partial Q_t}\frac{\partial Q_t}{\partial q_{1t}^i}(q_{1t}^i + q_{2t}^i) + W_t - P_{1t} - \frac{\partial P_{1t}}{\partial Q_{1t}}\frac{\partial Q_{1t}}{\partial q_{1t}^i} q_{1t}^i$$
$$- \frac{\partial P_{2t}}{\partial P_{1t}}\frac{\partial P_{1t}}{\partial Q_{1t}}\frac{\partial Q_{1t}}{\partial q_{1t}^i} q_{2t}^i\, \theta_1 - \theta_2\, (q_{1t}^i + q_{2t}^i). \quad (3.8)$$

From Eq. (3.5) and Eq. (3.6), it follows that $\frac{\partial W_t}{\partial Q_t} = \eta\frac{W_t}{Q_t}$ and $\frac{\partial P_{1t}}{\partial Q_{1t}} = \varepsilon\frac{P_{1t}}{Q_{1t}}$, and $\phi_t^i = \frac{\partial Q_t}{\partial q_{1t}^i} = \frac{\partial Q_{1t}}{\partial q_{1t}^i}$ since $Q_{2t} = \sum_{i=1}^{N} q_{2t}^i$ is taken as given. ϕ_t^i can be interpreted as packer i's perceived change of market output (material input) when its own market output (material input) changes. It is a measure of the market power packer *i* enjoys in the industry. If the packer is a price-taking firm, then $\phi_t^i = 0$, because he expects that changes in his own output will leave the market output unchanged. In another extreme, when packer *i* is a monopolist, then $\phi_t^i = 1$, because there is a one-to-one correspondence between packer i's output and the market output. In general, $\phi_t^i > 0$ indicates that packer *i* enjoys some degree of market power. To test whether the use of AMAs is the source of packers' market power, we model ϕ_t^i as

$$\phi_t^i = \theta_3 + \theta_4 q_{2t}^i + \theta_5 \sum_{j \neq i} q_{2t}^i + \theta_6 t, \tag{3.9}$$

where *t* is a time trend included as a proxy for the underlying market conditions. This specification approximates packer *i*'s conjecture in period *t* as a function of his own stock of live hogs from AMAs and the stocks of his competitors' AMAs supplies. If indeed the use of AMAs is the source of market power, then we should not reject the hypothesis that at least one of the two coefficients θ_4 and θ_5 is nonzero.

Incorporating all required changes in notation, Eq. (3.8) can be rewritten as

$$\eta \frac{W_t}{Q_t} \phi_t^i \left(q_{1t}^i + q_{2t}^i\right) + W_t = P_{1t} + \varepsilon \frac{P_{1t}}{Q_{1t}} \phi_t^i q_{1t}^i + \mu \frac{P_{2t}}{P_{1t}} \varepsilon \frac{P_{1t}}{Q_{1t}} \phi_t^i q_{2t}^i + \theta_1 + \theta_2 \left(q_{1t}^i + q_{2t}^i\right). \tag{3.10}$$

The term $\eta \frac{W_t}{Q_t} \phi_t^i \left(q_{1t}^i + q_{2t}^i\right)$ can be interpreted as a measure of packers' market power in the downstream pork market. In addition, the market power potentially benefits the packers in the upstream live hog markets in two ways. First, the term $\varepsilon \frac{P_{1t}}{Q_{1t}} \phi_t^i q_{1t}^i$ can be interpreted as the price markdown due to packers' market power in the spot market. The term $\mu \frac{P_{2t}}{P_{1t}} \varepsilon \frac{P_{1t}}{Q_{1t}} \phi_t^i q_{2t}^i$ represents the price markdown in the AMA supply channel due to packers' market power as well as various formula pricing clauses in marketing contracts. If the packer does not enjoy any market power, that is, $\phi_t^i = 0$, then Eq. (3.10) reduces to the equality between the marginal benefit of converting an additional live hog into pork, W_t, and the marginal costs, which include the cost of live hogs, P_{1t}, and the marginal production cost $\theta_1 + \theta_2 \left(q_{1t}^i + q_{2t}^i\right)$.

Estimation

Appending the first-order condition Eq. (3.10) with an additive optimization error term e_t^i with the property $E(e_t^i) = 0$, we can form the following moment condition

$$m_t^i(\theta) = e_t^i, \tag{3.11}$$

where

$$\begin{aligned} e_t^i = {} & \eta\frac{W_t}{Q_t}\phi_t^j\left(q_{1t}^i + q_{2t}^i\right) + W_t - P_{1t} - \varepsilon\frac{P_{1t}}{Q_{1t}}\phi_t^j q_{1t}^i \\ & - \mu\varepsilon\frac{P_{2t}}{Q_{1t}}\phi_t^j q_{2t}^i - \theta_1 - \theta_2\left(q_{1t}^i + q_{2t}^i\right). \end{aligned} \tag{3.12}$$

In fact, we form a moment condition for each of the N major packers; hence, there are N such moment conditions.

We also form the moment conditions for the inverse demand function for pork:

$$m_2(\theta) = Z_{dt}' e_{dt}, \tag{3.13}$$

where

$$e_{dt} = \log W_t - \gamma_0 - \eta\log(Q_t) - \gamma_1\log p_{bt} - \gamma_2\log p_{ct} \tag{3.14}$$

and Z_{dt} is a vector of instruments. To account for endogeneity of the market price for pork W_t and the output quantities Q_t, we form instruments Z_{dt} using supply-side cost shifters: the prices for soybean and corn, together with the exogenous variables in Eq. (3.14), that is, p_{bt} and p_{ct}.

Similarly, we form the moments for the inverse supply function of live hogs in the spot channel:

$$m_3(\theta) = Z_{1t}' e_{1t}, \tag{3.15}$$

where

$$e_{1t} = \log P_{1t} - \delta_0 - \varepsilon\log(Q_{1t}) - \delta_1\log p_{wt} - \delta_2\log p_{et} \tag{3.16}$$

and Z_{1t} is a vector of instruments. To account for endogeneity of the spot market price for live hogs P_{1t} and the quantities supplied Q_{1t}, we form instruments Z_{1t} using demand-side shifters: the price of poultry and the price of beef, together with the exogenous variables in Eq. (3.16), that is, p_{wt} and p_{et}.

Then, we form the moments for the relationship between the prices in two channels:

$$m_4(\theta) = Z_{4t}'e_{2t}, \tag{3.17}$$

where

$$e_{2t} = \log P_{2t} - \lambda_0 - \mu \log(P_{1t}) \tag{3.18}$$

and Z_{4t} is a vector of instruments. Because of various formula pricing clauses in marketing contracts, P_{1t} is an exogenous determinant of P_{2t}. As a result, there is no endogenous variable in Eq. (3.18). Thus, we form instruments Z_{4t} using the same variables in Eq. (3.18), that is, P_{1t}.

Finally, we stack all the moments together and form the following GMM estimator:

$$\theta = \text{argmin } U_T(\theta) = \left(T^{-1}\sum_{t=1}^{T} m(\theta)\right)' A \left(T^{-1}\sum_{t=1}^{T} m(\theta)\right), \tag{3.19}$$

where A is an appropriately chosen weighting matrix, and

$$m(\theta) = \begin{bmatrix} m_1^1(\theta) \\ \cdots \\ m_1^N(\theta) \\ m_2(\theta) \\ m_3(\theta) \\ m_4(\theta) \end{bmatrix}. \tag{3.20}$$

In this set up, we need to estimate 16 parameters: 6 from Eq. (3.12), 4 from Eq. (3.14), 4 from Eq. (3.16), and another 2 from Eq. (3.18). We use 20 moments: 8 for each of the major packers, 5 from Z_{dt}, 5 from Z_{1t}, and 2 from Z_{4t}. So the model is overidentified and allows us to perform an overidentification test to see whether the model and its specification can be rejected by the data or not.

The model has been estimated using company-level data, which means that in cases where one company operates multiple processing plants, the data have been aggregated across plants. We use the data for eight companies. These are eight of the top nine packers in terms of firm size. One packer, whose data were not used, never used spot markets for procuring live hogs during the time period covered by the data set. We used monthly data for the period October 2002 through March 2005 with a total of 30 observations per firm. In addition to company-level individual transactions (purchase) data, we also used Bureau of Labor Statistics indexes for U.S. city average prices of beef, veal, and poultry; total private-sector average hourly earnings of production workers; and the electric power price index.[7]

Table 3-1 provides the estimation results for the downstream inverse demand function for pork. All the estimates have the expected signs. The own price elasticity is negative. As the prices for beef and poultry increase, the price for pork also increases because they are substitutes.

Table 3-1. Estimation Results for Downstream Inverse Demand Function

Variable	Estimate	t-stat
γ_0	–10.0930	–1.18
γ_1	0.5501	1.55
γ_2	3.6392	4.02
η	–0.4317	–0.73

Table 3-2 presents the estimation results for the upstream inverse supply function for live hogs through the cash channel. Again, all the estimates have the expected signs. The own price supply elasticity is positive. As the price for live hogs goes up by 1%, the supply of live hogs through the cash channel will go up by approximately 0.23%. Also, as wages and the price of electricity go up, the prices farmers ask for their hogs will also go up.

Table 3-2. Estimation Results for Upstream Inverse Supply Function in the Cash Channel

Variable	Estimate	t-stat
δ_0	–34.90010	–3.95
δ_1	10.57840	6.01
δ_2	1.41260	2.10
ε	0.22674	0.91

[7] The data were obtained from the U.S. Department of Labor, Bureau of Labor Statistics Web site (www.bls.gov).

Estimation results for the price determination rule in the AMA supply channel are presented in Table 3-3. As expected, as a consequence of the formula pricing clauses in marketing contracts, the AMA supply price is closely related to the spot price. A 1% increase in the cash price corresponds to a 0.85% increase in the AMA supply price.

Table 3-3. Estimation Results for Price Determination Rule in the AMA Supply Channel

Variable	Estimate	t-stat
λ_0	0.6150	7.90
μ	0.8499	44.45

Finally, Table 3-4 summarizes the estimation results for the cost function and the market power function. Two main results are worth emphasizing. First, the results indicate the presence of statistically significant market power in the industry because the constant term in the market power function, θ_3, is positive and significant. This reinforces the result previously obtained with the aggregate data. Second, the two main parameters of interest in this study, θ_4 and θ_5, are not statistically significant, thus indicating that AMAs may not be a source of market power in pork packing. This is different from the result previously obtained using the aggregated industry-level data. Further investigation into possible sources of market power could be interesting but is beyond the scope of the study.

Table 3-4. Cost Function and Market Power Estimation Results

Variable	Estimate	t-stat
θ_1	50.15690	108.46
θ_2	–0.00001	–5.81
θ_3	0.48160	3.20
θ_4	–2.79e-08	–0.56
θ_5	2.28e-08	0.57
θ_6	0.00090	0.39

3.2 ECONOMIES OF SCALE IN PORK PACKING

Returns or economies to scale are most appropriately measured by the relationship between total cost and output along the expansion path where input prices are constant and costs are minimized at every level of output (Hanoch, 1975). For this study we chose the translog cost function because it allows the economies of scale to vary with the level of output. This feature enables the average cost curve to attain the classical U-shape.[8] Once the estimates of the total cost function are obtained, the economies of scale measure is obtained as unity minus the elasticity of total cost with respect to output:

$$ES \equiv 1 - \frac{\partial logC}{\partial logY} \tag{3.21}$$

which results in positive numbers for the increasing (positive) returns to scale and negative numbers for the decreasing (negative) returns to scale. The elasticity of total cost with respect to output, however, has to be positive because the theoretically correct cost function must be nondecreasing in output. Multiplying Eq. (3.21) by 100 yields estimates of economies of scale expressed in percentage terms. This approach has been prominently used in various industry studies of cost efficiency and economies of scale; see, for example, Christensen and Greene (1976) and Atkinson and Halvorsen (1984).

3.2.1 Econometric Model

The limited availability of information dictates the specification of a cost function that exhibits three problems, none of which is in our opinion very severe. First, the only separate cost component that can be disentangled from the rest of the total cost is the cost of live animals. Therefore, we assume that the production of pork is a function of the number of animals slaughtered and some other generic production input that jointly represents labor, capital, energy, and other intermediary inputs used in meat packing. Therefore, we can only identify the percentage cost shares of live animals and the other generic production input in the total cost structure of packing plants.

[8] The translog functional form provides a convenient second-order approximation to an arbitrary continuously twice-differentiable cost function (see Diewert [1974]).

Second, we assume that firms/plants produce the homogeneous product called “pork,” which is measured by the total carcass or hot weight of slaughtered animals. Because the P&L statements generally do not report carcass weight data, we calculated the average monthly, plant-level, carcass weight per incoming animal and applied that number to the number of head killed as reported in the plant’s P&L statements to obtain the measurement of pork output.[9]

Finally, estimation of the standard cost function requires having data on input prices. The price of live animals was recovered from the individual transactions data. The problem is getting the price for the generic input mentioned above. Because the labor cost appears to be the most important component in the mix of production inputs other than live animals, we used the average weekly earnings of production workers (not seasonally adjusted) for the industry “Meat Processed from Carcasses” (NAICS 311612) and “Rendering and Meat Byproduct Processing” (NAICS 311613) from the Bureau of Labor Statistics data.

The translog cost function for the two inputs case can be written as

$$\begin{aligned} logC = \; & \alpha_0 + \alpha_Y logY + \frac{1}{2}\gamma_{YY} (logY)^2 + \alpha_1 logP_1 + \alpha_2 logP_2 + \\ & \frac{1}{2}[\gamma_{11}(logP_1)^2 + \gamma_{12} logP_1 logP_2 + \gamma_{21} logP_2 logP_1 + \\ & \gamma_{22}(logP_2)^2] + \gamma_{Y1} logY logP_1 + \gamma_{Y2} logY logP_2, \qquad (3.22) \end{aligned}$$

where $\gamma_{12} = \gamma_{21}$, C is total cost, Y is pork output, P_1 is the price of market hogs, and P_2 is the wage rate. To correspond to a well-behaved production function, a cost function must be homogenous of degree 1 in input prices, which requires imposing the following set of restrictions on the parameters:

$$\begin{aligned} \alpha_1 + \alpha_2 &= 1 \\ \gamma_{Y1} + \gamma_{Y2} &= 0 \\ \gamma_{11} + \gamma_{12} &= \gamma_{21} + \gamma_{22} = \gamma_{11} + \gamma_{12} + \gamma_{21} + \gamma_{22} = 0. \qquad (3.23) \end{aligned}$$

[9] The month-by-month comparison of the number of purchased market hogs from the individual transactions data and the number of hogs killed from the P&L data indicate that the two series are reasonably close to each other. The average 30-month ratio of two numbers is between 0.9 and 1 for all but two plants.

In addition to imposing the linear homogeneity in input prices, we also test whether our cost function is based on a homothetic production structure. A cost function corresponds to a homothetic production function if and only if the cost function can be written as a separable function in output and factor prices (see Diewert [1974]). For the translog cost function, the homotheticity restriction translates into the requirements that

$$\gamma_{Y1} = 0 \quad \text{and} \quad \gamma_{Y2} = 0. \tag{3.24}$$

If this restriction is valid, it is preferable to adopt the simplified model.

The optimal procedure to estimate the above cost function and obtain the estimates of the economies of scale is to jointly estimate the cost function and the cost share equations as a multivariate regression system. The cost share equations for each factor input are easily obtainable using Shephard's lemma:

$$\begin{aligned}\frac{\partial logC}{\partial logP_1} &= S_1 = \alpha_1 + \gamma_{Y1} logY + \gamma_{11} logP_1 + \gamma_{12} logP_2\\ \frac{\partial logC}{\partial logP_2} &= S_2 = \alpha_2 + \gamma_{Y2} logY + \gamma_{21} logP_1 + \gamma_{22} logP_2.\end{aligned} \tag{3.25}$$

The estimation procedure that we use involves estimating the translog cost function Eq. (3.22) together with one of the two share equations Eq. (3.25) by imposing the cross-equation restrictions on the identical parameters in the cost function and the share equation, using iterative Zellner seemingly unrelated regression (ZSUR).[10] The linear homogeneity in input prices restrictions Eq. (3.23) is imposed throughout, and the homotheticity restrictions are tested separately. All restrictions are tested using likelihood ratio tests.

Based on the estimated parameters of the translog cost function, the economies-of-scale measure can be calculated as follows:

$$ES = 1 - (\hat{\alpha}_Y + \hat{\gamma}_{YY} logY + \hat{\gamma}_{Y1} logP_1 + \hat{\gamma}_{Y2} logP_2). \tag{3.26}$$

[10] Barten (1969) has shown that maximum-likelihood estimates of a system of share equations with one equation deleted are invariant to which equation is deleted. Dhrymes (1970) has shown that iteration of the ZSUR procedure until convergence results in maximum-likelihood estimates.

In cases when the homotheticity assumption holds, the returns-to-scale formula will differ by $\gamma_{Y1} = 0$ and $\gamma_{Y2} = 0$.[11] The returns to scale can be calculated for the industry as a whole by evaluating Eq. (3.26) at the sample means for output and input prices. Alternatively, the economies of scale can be calculated for each plant by evaluating Eq. (3.26) at the plant-level means for output and input prices.

3.2.2 Empirical Results

In addition to the packers' survey data and the individual transactions data, we used the monthly P&L data from 18 plants. In cases where packers reported weekly P&L data, the numbers were aggregated to obtain monthly observations. All but two plants are involved in slaughter, fabrication, and processing of live hogs; the remaining two are engaged only in slaughter and fabrication.

The econometric model is estimated using two data sets. The large data set contains 16 plants that are involved in all three stages of production (slaughter, fabrication, and processing), and the small data set contains the remaining two plants that are involved only in the first two stages and have no further processing. The estimation results for the large group are presented in Table 3-5. The estimation results for the small group cannot be reported because of the violation of confidentiality rules. The results show that the linear homogeneity in input prices Eq. (3.23) is a valid restriction (i.e., we cannot reject that null hypothesis). Second, based on the results from the nonhomothetic specification (Model A), we cannot reject the null hypothesis that the underlying production technology is homothetic, so we estimated the homothetic version of the model as well (Model B).

The estimated economies of scale under two different specifications of technology are represented in Table 3-6. We partitioned the large sample of 16 plants into three groups according to size. Each row in the table presents the results for a hypothetical representative plant that belongs to that size group. The results confirm our expectation that economies of scale diminish as plant size increases. The estimates indicate

[11] An even simpler model can be obtained by restricting a homothetic production structure to be homogeneous. This will be the case if and only if the elasticity of cost with respect to output is constant and equal to α_Y.

Table 3-5. Translog Cost Function Parameter Estimates: 16 Hog Slaughter Plants with All Three Production Stages

	Model A		Model B	
Parameter	**Estimate**	**t-Ratio**	**Estimate**	**t-Ratio**
α_0	21.039	1.28	21.714	1.32
α_y	–1.878	–1.01	–1.974	–1.07
γ_{yy}	0.160	1.53	0.166	1.60
α_1	1.125	2.78	0.611	11.82
α_2	–0.125	–0.31	0.389	7.53
γ_{11}	–0.050	–2.02	–0.052	–2.09
γ_{12}	0.050	2.02	0.052	2.09
γ_{22}	–0.050	–2.02	–0.052	–2.09
γ_{y1}	–0.029	–1.28		
γ_{y2}	0.029	1.28		
R^2	0.6926		0.6923	
Restriction[a]	**Homogeneous of Degree 1 in Input Prices**		**Homotheticity**	
			LM = –56.8598	t-ratio = –1.28 P value = 0.2009

[a] The restriction for homotheticity is not significant (p = 0.2009), which implies that the data are consistent with the restriction.

Table 3-6. Hog Slaughter Plant Economies of Scale Measures

		Model A		Model B	
Plant Size	**Capacity**[a]	**Economies of Scale**	**Efficient Scale**[b]	**Economies of Scale**	**Efficient Scale**[b]
Large plants	91,111	–0.070	46,562	–0.031	60,123
Medium plants	52,675	–0.012	46,485	0.030	60,123
Small plants	41,311	0.065	44,327	0.118	60,123

[a] Capacity is expressed as monthly carcass weight in 1,000 pounds.
[b] Efficient scale is the point of minimum average cost in 1,000 pounds.

that scale economies are exhausted well within the sample output range such that the largest plants already exhibit negative economies of scale. For example, based on Model A, for a plant with a capacity of producing 91 million pounds of carcass weight per month (that would correspond to a slaughter capacity of approximately 110,000 market hogs per week),[12] the economies of scale are –7.0%, which means that an increase in output of 1% will increase the total cost by

[12] The capacities expressed in monthly carcass weights were obtained by multiplying the weekly slaughter capacities (in number of hogs) by 4.25 weeks per month and then multiplied again by the plant average monthly carcass weight per head.

1.07%. The result based on the homothetic production technology is –3.1%.

As plant size decreases, the negative economies of scale monotonically converge towards constant returns to scale. For example, for a plant that processes about 53 million pounds of carcass weight per month (about 65,000 hogs per week), according to Model A, the negative economies of scale amount to –1.2%, whereas according to the homothetic specification, the same plant already exhibits positive economies of scale in the amount of 3.0%. Finally, for the smallest plants, the economies of scale are clearly positive. Based on Model B, the plant that processes about 41 million carcass pounds per month (about 50,000 hogs per week) exhibits positive returns to scale in the amount of 11.8%, which means that an increase in output of 1% would increase the total cost by 0.882%.

A convenient way to summarize scale economies is to present the average cost curves facing various size plants. The cost curves are derived by evaluating the average cost function for a range of outputs holding the factor prices fixed at the sample means. The slope of the average cost curve is sufficient to infer the presence of economies of scale since $SE = 1 - (MC/AC)$. Declining average costs indicate increasing returns to scale, whereas rising average costs indicate decreasing economies of scale. The average cost curves for three representative plants are presented in Figures 3-1 through 3-3. Inspection of these graphs indicates that different size plants operate on different segments of their average cost curves,[13] but that their efficient scales of operations (minimum average cost) are narrowly clustered around 44 to 47 million pounds per month. As Table 3-6 shows, the efficient scale of production under homothetic technology is quite a bit larger (60 million pounds of carcass weight per month) and the same for all plants irrespective of size.[14]

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[13] Black diamonds indicate the values of the average cost curves fitted with the output levels within the data range, whereas the paler squares indicate out-of-sample fits.

[14] Constant efficient scale of production is an algebraic artifact of the homothetic production technology. In our opinion, nonhomothetic technology, which was statistically refuted in favor of the homothetic technology, represents a more realistic description of meat processing than homothetic technology, precisely because under nonhomothetic technology the efficient scale of production varies with the size of the operation.

Figure 3-1. Average Cost for a Representative Plant in the Small Size Group

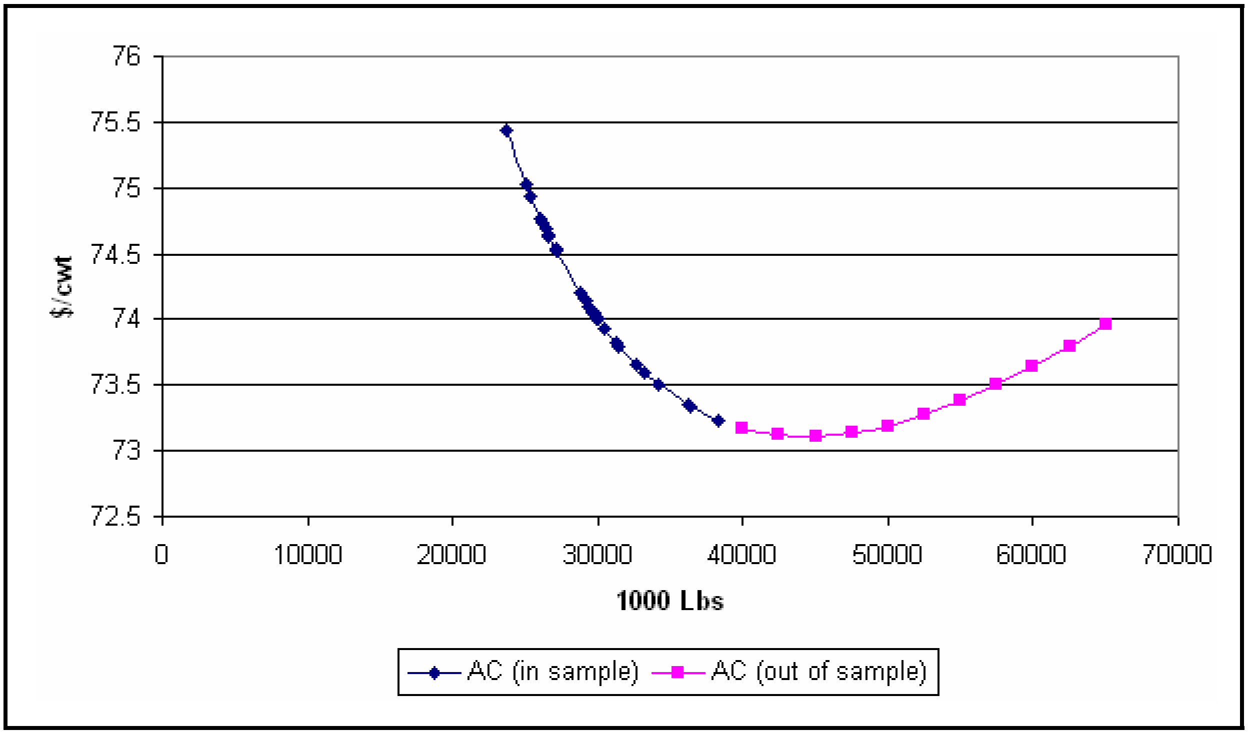


Figure 3-2. Average Cost for a Representative Plant in the Medium Size Group

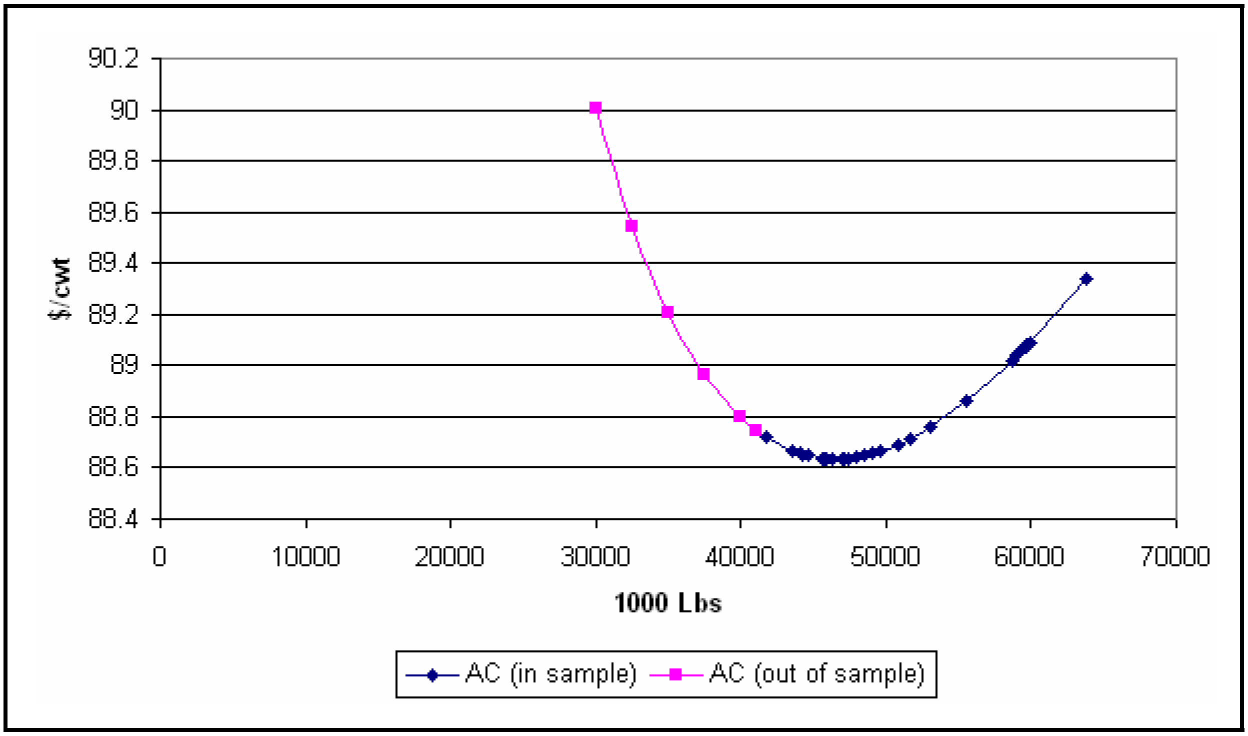
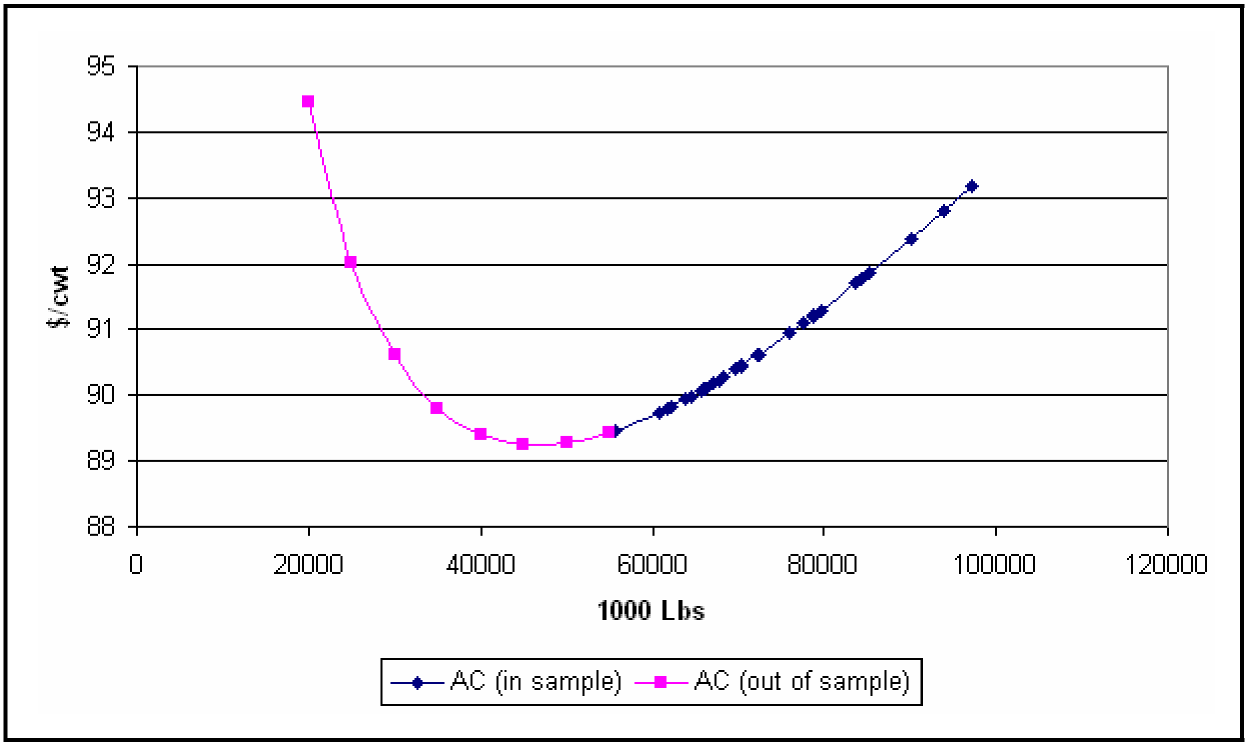


Figure 3-3. Average Cost for a Representative Plant in the Large Size Group



3.3 COMPLEMENTARITY OF MARKETING ARRANGEMENTS

The modern theory of the firm has made considerable progress in explaining the determinants of vertical integration and firm boundaries, assuming that the level of vertical integration results from independent transactional choices by the firm. However, for most organizations, firm boundaries are not determined by independent vertical integration decisions but depend on interrelated choices spanning functional activities. A common finding of the early empirical literature on organizations in firms (e.g., Arora and Gambardella [1990]; MacDuffie [1995]) was that organizational design practices are clustered, meaning that adopting one practice is correlated with adopting other practices; consequently, clusters of practices consistently appear together. The interdependencies among practices can be crucial for determining the payoffs for individual practices (Milgrom and Roberts, 1990; Levinthal, 1997).

In a frequently cited paper, Milgrom and Roberts (1990) developed a theoretical model of the firm that allows them to explore complementarities in modern manufacturing firms. The nonconvexities (some decision variables are naturally integer valued), together with the fact that the firm's objective function itself may be nonconcave, nondifferentiable, and even discontinuous at some points, prevent the use of differential calculus techniques to derive the comparative statics results. Instead they use purely algebraic (lattice-theoretic) methods based on the concept of supermodularity, which provides an exact formalization of the idea of groups of complementary activities. Complementarities lead to predictable relationships among activities. A decision to increase the level of one activity will raise the profitability of any contemplated increases in levels of any complementary activities. Therefore, high levels for all the elements of a group of complementary activities go together.

Complementarity between continuous practices can be defined using the second-order cross partial derivatives. Let f be a function of practices $(x_1, x_2, \ldots, x_n)$. Practices x_i and x_j are complementary in the function f if and only if $\partial^2 f / \partial x_i \partial x_j \geq 0$ and strict inequality holds at least one value of $(x_1, x_2, \ldots, x_n)$. In other words, complementarity exists if the implementation of one practice increases the marginal return of the other practice.

In the case where the practices $(x_1, x_2, \ldots, x_n)$ are measured by the discrete measure, complementarity between two practices can be defined using the concept of the supermodularity. A function f is supermodular if, for all $x, x' \in R^n$,

$$f(x \vee x') + f(x \wedge x') \geq f(x) + f(x'), \tag{3.27}$$

where $x \vee x'$ is the vector whose ith element is $max(x_i, x_i')$ and $x \wedge x'$ is the vector whose ith element is $min(x_i, x_i')$. Note that supermodularity is defined in terms of ordinal rank. Based on the definition of supermodularity, the condition for complementarity between the practices x_1 and x_2 is written as

$$\begin{aligned} &f(x_1 + 1, x_2 + 1, x_3, \ldots, x_n) + f(x_1, x_2, x_3, \ldots, x_n) \geq \\ &\quad f(x_1 + 1, x_2, x_3, \ldots, x_n) + f(x_1, x_2 + 1, x_3, \ldots, x_n). \end{aligned} \tag{3.28}$$

In the rest of this section, we explore whether various marketing arrangements in pork procurement and packing may be complementary to each other. In particular, we are interested in determining whether the efficient scale of production systematically varies with the portfolio of marketing arrangements used by the plant to acquire hogs. In addition, we also investigate the relationship between use of marketing arrangements and two other firm-level performance measures: the gross margin defined as the total revenue minus the cost of live animals and earnings before interests and taxes (EBIT).

3.3.1 Correlation Results

As a preliminary step in testing for complementarities, one can look at the unconditional associations among marketing arrangements (see Miravete and Pernias [2006]). We performed two different tests: the unconditional association of strategies using the Kendall Tau correlation coefficient,[15] and the conditional association among strategies using a multivariate probit model.

The marketing arrangement data are from the packers' survey and from the individual transactions (purchase) data. In the packers' survey data set, we have marketing arrangement data from 85 plants, and from the individual transactions data set, we have observations from 29 large plants. The data sources differ substantially primarily because the size of the plants differs. According to the packers' survey, the most widely used purchase method is MA1 (spot market only), followed by the MA1–MA2 (spot-marketing contracts) portfolio. Production contracts (MA4), which do not exist as a separately defined category in the individual transactions data set, occur only rarely in the MA3–MA4 portfolio and in the MA1–MA2–MA4 portfolio. According to the individual transactions (purchase) data, the most frequently used portfolio is MA1–MA2, followed by MA1–MA2–MA3, and then MA2–MA3–MA4.[16] For the group of 18 plants for which P&L data are available, the marketing arrangement portfolios are used in the following order of frequency: MA1–MA2, MA1–MA2–MA3, MA2–MA3–MA4, and MA1.

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[15] For the discussion about the advantages and disadvantages of using various correlation coefficients, see Miravete and Pernias (2006, pp. 8-9).

[16] Notice that MA4 in the individual transactions data is the category "Other" and is therefore different than MA4 in the packers' survey, where it represents production contracts. To the extent that the "Other" category may include production contracts as well, the difference between these two definitions may not be that large.

The Kendall Tau was computed using the data on marketing arrangement portfolio choices from the packers' survey data set (85 observations) and from the individual transactions (purchase) data set for plants for which we also have usable P&L data (18 observations). The multivariate probit model was estimated with the packers' survey data only (82 observations). All tests were performed using three channels: MA1—cash/spot markets, MA2—marketing contracts, and MA3—packer owned and production contracts (in the survey data set) or packer owned and other (in the individual transactions data set). The reasons for collapsing the original four channels into three channels were strictly numerical (some matrices were singular or solution algorithms did not converge). All results, summarized in Table 3-7, are qualitatively identical.

Table 3-7. Hog Slaughter Plant Association of Marketing Arrangements

	Unconditional Association		Conditional Association
Marketing Arrangement	**Kendall Tau P&L Data**	**Kendall Tau Packers' Survey Data**	**Multivariate Probit[a] Packers' Survey Data**
MA1, MA2[b]	–0.108 (0.655)[c]	–0.342 (0.002)	–0.930 (0.000)
MA1, MA3	–0.500 (0.039)	–0.330 (0.003)	–0.647 (0.001)
MA2, MA3	0.217 (0.371)	0.378 (0.001)	0.590 (0.008)
N	18	85	82

[a] The numbers shown are correlation coefficients between the residuals with P values in parentheses.

[b] MA1: Cash/Spot Sales; MA2: Marketing Contracts; MA3: Packer Owned/Other (for P&L data) and Packer Owned/Production Contract (for packers' survey)

[c] Asymptotic P values in parentheses.

The Kendall Tau statistics show that MA1–MA2 and MA1–MA3 are substitutes (negative values for τ), but MA2–MA3 are complements (positive values for τ). The results are significant in the packers' survey data and not significant in the P&L data. The conditional association test was performed by estimating a multivariate probit model. In this approach, we test for the conditional correlation of the residuals obtained from estimating the system of three equations with the left hand side (LHS) variables representing firms' choice, defined as D_{ij} = 1 if plant i, (i =1, 2,…, 85) uses marketing arrangement j, (j =1, 2, 3), and D_{ij} = 0 otherwise, on a vector of observable exogenous control variables. The vector of exogenous variables includes the capacity of the plant, the size of the company measured by the number of plants it operates, and two regional binary variables.[17] The results are essentially the same as before, showing that only the MA2–MA3 pair may be complements.

3.3.2 Performance Approach

The performance approach to complementarity testing involves regressing some firm-level performance measure (π_i) on all combinations of marketing arrangements (i.e., portfolios) and a vector of exogenous control variables X (see, for example, Ichniowski, Shaw, and Prennushi [1997]). In estimating the impact of various marketing arrangement portfolios on a performance measure, we want to avoid any possible selection bias resulting from nonrandom selection of marketing arrangement portfolios. The most likely reason for nonrandom selection of marketing arrangements is that most innovative plants will choose the most innovative procurement practices.

In a panel data framework, one can control for this potential source of bias with a plant-level fixed-effects specification. Alternatively, to deal with endogeneity, one can use a two-stage discrete/continuous procedure outlined in Train (1993, pp. 87-91). In the first stage, one would estimate the multinomial logit (or probit) where the LHS variable is a categorical variable for each of the existing combinations (portfolios) of marketing arrangements, and the right hand side (RHS) variables are some exogenous variables explaining the choice. The obtained coefficient estimates from the first stage are used to generate the expected values for each firm adopting a certain portfolio. In the second stage, these predictions are used as the explanatory variables in the performance equation. OLS is a consistent estimator for this performance equation. However, these estimates may not be efficient, requiring the use of bootstrapping to obtain correct confidence intervals.

The estimated coefficients associated with various marketing arrangement portfolio variables, even if they show significant positive effects on some performance measure, do not compare the effects of individual marketing arrangements with those of portfolios of marketing arrangements, and therefore do not provide unambiguous evidence on whether the individual

[17] The coefficient estimates of the multivariate probit model and their standard errors are suppressed for brevity but are available upon request.

marketing arrangements that comprise the portfolio are complementary. Complementarity among marketing arrangements implies that the magnitude of the productivity effect of the portfolio of marketing arrangements is larger than the sum of the marginal effects from adopting each marketing arrangement. A formal test of complementarity requires adding the individual marketing arrangement binary variables to the regressions containing marketing arrangement portfolio binary variables and comparing the magnitudes of individual versus portfolio effects.

3.3.3 Empirical Results

The performance equations are estimated using three different performance measures. First, based on the estimated cost function parameters for nonhomothetic technology (Model A), we computed the efficient scale of operations (minimum average cost) for 18 plants in the data set (see Table 3-6). The efficient scale of operation may be influenced by the portfolio of marketing arrangements used to procure live hogs for two reasons. The portfolio of marketing arrangements may affect the average cost function through increased capacity utilization, through lower average factor prices (live hogs prices), or through both. The performance equation using efficient scale is estimated using 18 observations only.

The other two performance measures are gross (meat) margin and EBIT (profit). For both of those, the portfolio of marketing arrangements used to procure hogs may be important because, in addition to influencing the cost side, it can also potentially impact the revenue side of the meat margin or profit. The idea is that different portfolios of marketing arrangements may result in the procurement of different average-quality live hogs, which when slaughtered and processed may yield higher quality pork that will be sold at higher market prices. These two performance equations are estimated using the panel data with 30 monthly observations for 18 plants. The 18 plants included in this data set differ significantly according to their size. The largest plant has a maximum weekly slaughter capacity several times larger than that of the smallest plant. Thus, we standardized the gross margin and the EBIT variables based on the plant capacity.

Table 3-8 provides the estimates of all three performance equations where no attempt was made to correct for a possible endogeneity of marketing arrangement portfolios. Portfolio 1, which contains only cash/spot purchases of live hogs, was left out of the regression to avoid perfect collinearity. Aside from portfolio binary variables, the only other RHS variables included in the regressions performed with the panel data are time and time squared. Time is included to account for all possible macroeconomic influences that may be affecting the plants' performance. The efficient scale regression is performed with cross-sectional data and hence does not have time as explanatory variable. The units of the portfolio coefficients for the efficient scale regression are expressed in thousands of pounds of monthly carcass weight capacity, and those in the gross margin and EBIT regressions are in dollars per hog.

Table 3-8. Estimated Performance Effects of Different Marketing Arrangement Portfolios

Marketing Arrangement Portfolio	Efficient Scale (18 Observations)	Gross Margin/Capacity (540 Observations)	EBIT/Capacity (540 Observations)
Portfolio 2[b]	37086.85[a] (11081.34)*	34.512 (13.95)*	1.712 (0.9583)
Portfolio 3	40202.7 (11516.07)*	100.315 (14.497)*	0.204 (0.9959)
Portfolio 4	43421.95 (12139)*	27.579 (15.281)	6.971 (1.05)*
Time		0.9862 (1.49)	0.1568 (0.1023)
Time squared		–0.0107 (0.0466)	–0.0055 (0.0032)
Constant	2536.472 (10512.69)	–1.719 (16.302)	1.032 (1.12)
Adjusted R^2	0.3922	0.1641	0.1735

[a] The numbers shown are estimated coefficients with standard errors in parentheses. An asterisk indicates significance at the 0.05 level.

[b] Portfolio 1: Cash/Spot Sales; Portfolio 2: Cash/Spot + Marketing Contracts; Portfolio 3: Cash/Spot + Marketing Contracts + Packer Owned/Other; Portfolio 4: Marketing Contracts + Packer Owned/Other.

The results are relatively similar across all three performance equations. All portfolio binary variables are positive and most are significant at the 5% level. These results indicate that various combinations of marketing arrangements improve plant performance relative to the situations in which the plant uses only cash/spot markets to purchase all of its live hogs.

Because the adoption of different marketing arrangement portfolios is likely to be nonrandom, the problem of selection bias needs to be addressed. In our panel data (30 monthly observation times 18 plants), the plant-level marketing arrangement portfolios do not change over time. In this case, subtracting the plant-specific time series mean would zero out all marketing arrangement portfolio binary variables, rendering the fixed effects estimation impossible. On the other hand, because our cross-sectional data set has only 18 observations, estimating the multinomial logit in the first stage of the Train (1993) procedure is fairly unreliable. Therefore, we use the 2SLS estimator. Because we have three endogenous variables (portfolios 2, 3, and 4), we must include at least three instruments. We use the size of the company as measured by the number of plants that it operates, size squared (to capture some nonlinearities), and the interaction between the size of the plant and the region where it is located. We do not include simple regional binary variables because including them causes collinearity problems. We hypothesize that all of these variables influence a company's decision about which portfolio of marketing arrangements to select.[18] The results of estimation are presented in Table 3-9.

Table 3-9. Instrumental Variable (2SLS) Estimates of Performance Equations

Marketing Arrangement Portfolio	Efficient Scale (18 Observations)	Gross Margin/Capacity (540 Observations)	EBIT/Capacity (540 Observations)
Portfolio 2[b]	43622.34[a] (22727.91)	217.544 (36.612)*	10.584 (1.828)*
Portfolio 3	40911.03 (19833.6)*	154.614 (31.95)*	5.035 (1.595)*
Portfolio 4	31749.24 (23130.3)	314.837 (37.261)*	16.908 (1.86)*
Time		0.9862 (2.325)	0.1568 (0.1161)
Time squared		–0.01067 (0.0728)	–0.0055 (0.0036)
Constant	1017.42 (20047.32)	–156.194 (35.548)*	–6.402 (1.775)*
R-squared	0.0858	0.1238	0.1864

[a] The numbers shown are estimated coefficients, with standard errors in parentheses. An asterisk indicates significance at the 0.05 level.

[b] Portfolio 1: Cash/Spot Sales; Portfolio 2: Cash/Spot + Marketing Contracts; Portfolio 3: Cash/Spot + Marketing Contracts + Packer Owned/Other; Portfolio 4: Marketing Contracts + Packer Owned/Other.

[18] It is interesting to note that the portfolios of marketing arrangements do not change across different plants owned by the same company. Based on this observation, we believe that the live hogs procurement strategy is determined at the company level rather than at the plant level.

The coefficients associated with various binary variables are all positive and most of them are significant at the 5% level, indicating that relative to the left-out binary variable for the spot market only, all other portfolios improve the economies of scale, the normalized gross margin, and the normalized EBIT. However, the magnitudes of the coefficients do not monotonically increase as expected. In other words, the magnitude of the Portfolio 3 binary variable, which contains all three marketing arrangements (cash, marketing contracts, and packer owned), is smaller than the Portfolio 2 binary variable, which includes only two marketing arrangements (cash and marketing contracts), signaling that including packer-owned hogs in the portfolio that already includes spot procurement and marketing contracts does not increase the performance of the plant. Interestingly, for both financial indicators (gross margin and EBIT), the magnitude of the Portfolio 4 coefficient is higher than the other two, indicating that the combination of marketing contracts and packer owned arrangements improves the performance of the plant relative to portfolios that include only spot market procurement. Therefore, based on these results, it is impossible to unambiguously conclude whether different marketing arrangements are actually complementary to each other.

As mentioned before, the rigorous test of complementarity among marketing arrangements would require adding the individual marketing arrangement binary variables to the regressions in Table 3-9 to compare the magnitudes of individual versus portfolio effects. Unfortunately, this procedure is not feasible because the individual marketing arrangement binary variables can only be assigned to individual observations (lots). Because this model has been estimated with monthly data, the monthly aggregation of marketing arrangements across lots gives exactly the portfolio of marketing arrangements that has already been used in estimation. This type of test can only be carried out using disaggregated individual lot data. However, it is not feasible to construct such a disaggregated performance measure unless one is willing to use purchase price for this purpose. Such a model has been estimated in Section 2, where we explain the sources of price differences across marketing arrangements.

3.4 SUMMARY

In this section, we identify and measure cost and efficiency differences associated with different marketing arrangements used to procure hogs. Procurement costs, operating costs, and selling costs can all be associated with different marketing arrangements. They can have differing effects on economies of scale and other performance measures, such as profitability or gross (meat) margin. The main difficulty in identifying cost and efficiency differences is separating any market power effects from purely cost changes associated with changes in marketing arrangements. For the purposes of testing whether market power exists and whether the source of that market power could be related to the use of AMAs in procurement of market hogs, we estimated two models. The first model is based on the industry-level data, and the second approach relies on the individual transactions data from large packers. Both approaches found a statistically significant presence of market power in procuring live hogs. The results regarding the significance of AMAs in explaining the sources of that market power are inconclusive. Whereas the industry-level data model, based on the farm–wholesale price spread, shows that a higher proportion of AMA supplies leads to increased market power, the model estimated with the company-level individual transactions data tells us that the use of AMA supplies may not be a source of market power in pork packing.

The estimated total and average cost functions confirm our expectations that economies of scale diminish as firm size increases. The estimates indicate that the scale economies are exhausted well within the sample output range such that the biggest plants already exhibit negative returns to scale (i.e., they operate on the upward-sloping portions of their average cost curves). As plant size decreases, the negative economies of scale monotonically converge toward constant returns to scale. The observed patterns of procurement portfolio choices by packers also indicate that certain combinations of marketing arrangements may reduce cost or increase economies of scale. In particular, relative to the use of spot market procurements alone, all other marketing arrangement portfolios increase the efficient scale of production.

Based on the observation that packers use marketing arrangements in clusters (portfolios), we started with a notion that marketing arrangements may be complementary to each other in the sense that implementing one procurement practice may increase the marginal return of the other practice. Testing for complementarities turns out to be important for measuring the economic effects of a regulation. If marketing arrangements are complements, a restriction that would ban or constrain the use of one marketing arrangement would have a direct effect reflected in an economic loss, because the practice is no longer available. It also will have an indirect effect arising from the fact that the regulated practice may be complementary to some other unregulated practice, and the efficiency of the unregulated practice may be diminished as its complementary practice use is reduced or eliminated.

The analyses of the complementarity of marketing arrangements produced inconclusive results. Although some simpler tests based on the correlation/association approach indicate that marketing contracts are in fact complementary to production contracts and/or packer owned arrangements, the portfolio coefficients in the performance equations based on either EBIT or gross margin do not monotonically increase with the portfolio order. In other words, all marketing arrangement portfolios improve plant performance relative to the simple spot market purchases, but the coefficient associated with the portfolio of three marketing arrangements is smaller than the coefficient associated with portfolios of two marketing arrangements. More conclusive formal tests were not feasible given data limitations.

4 Quality Differences Associated with Alternative Marketing Arrangements

This section analyzes the differences in the quality of finished market hogs (barrows and gilts) intended for slaughter across marketing arrangements through which they were procured. Regardless of the marketing arrangement used to procure the finished market hogs, the animals are shipped to a packer, and after being slaughtered, the carcasses are inspected for wholesomeness by USDA/FSIS or by a state government inspection system. Unlike beef, pork is rarely quality graded by USDA/AMS.[1] Instead packers rely on other measures of quality.

[1] See the official standards for swine in the Official United States Standards for the Grades of Slaughter Swine promulgated by the Secretary of Agriculture under the Agricultural Marketing Act of 1946 (60 Stat. 1087; 7U.S.C. 1621-1627), with amendments effective January 14, 1985. The USDA standards segregated swine according to intended use (slaughter or feeder), class (sex), and grade (apparent relative excellence and desirability for particular use). Grades of slaughter barrows and gilts were predicated on the same two general considerations that provided the basis for the grades of barrow and gilt carcasses: quality (which includes characteristics of the leanness and firmness of fat) and characteristics related to the combined carcass yields of the four lean cuts (ham, loin, picnic shoulder, and Boston butt). With respect to quality, two general levels were considered. Barrows and gilts with characteristics indicating that the carcass will have acceptable belly thickness and lean quality and acceptable firmness of fat receive grades U.S. No. 1–4, whereas others are graded as U.S. Utility. The grades U.S. No. 1–4 were based entirely on the

The pork industry began using its own measurements and away from grades in the early 1990s. The main problem with the USDA standards was that slaughtered animals were not well differentiated by quality, so approximately 85% or more of the hogs were graded as U.S. No. 1–2.

In this section, we first test whether the average quality attributes are significantly different across marketing arrangements. We use seven different quality characteristics: average lean percentage, loin-eye area, average loin depth, average backfat, average sort loss, average carcass weight, and fat-free lean index. The results show that alternative marketing (procurement) channels generate hogs of different quality, and the ordering of AMAs is not unique but varies across quality attributes. We then try to establish the relationship between the procurement methods for live hogs intended for slaughter and the quality of obtained meat products. We assume that higher quality live hogs should yield a higher proportion of higher priced meat cuts in the total sales bundle. We calculate a simple correlation coefficient between the meat quality index and the percentage share of purchases in the total purchases of live hogs. The obtained positive and statistically significant correlation coefficient supports our hypothesis.

The analyses in this section are based on MPR data. Individual transactions data were not used because the only quality attribute that we could consistently recover from the majority of records was the loin-eye depth, whereas the MPR data allowed as to look at seven different quality attributes.

4.1 RANKING OF MARKETING ARRANGEMENTS BY QUALITY ATTRIBUTES

For the analysis of live hog quality differences across various marketing channels, we used *USDA/AMS Mandatory Price*

combination of factors that predict the expected combined carcass yields of the mentioned four lean cuts. The official grade for slaughter barrows and gilts having acceptable quality was determined by considering two characteristics: backfat thickness over the last rib and the muscling score. Values of these factors were then used in a mathematical equation to arrive at the final grade.

Reports (hereafter, MPR).[2] As described in Section 2, the marketing channels are as follows:

- **Negotiated Purchases (MA1)**
- **Other Market Formula Purchases (MA2)**
- **Swine or Pork Market Formula Purchases (MA3)**
- **Other Purchase Arrangements (MA4)**
- **Packer Owned (MA5)**
- **Packer Sold (MA6)**

The definitions of quality indicators used in this study based on MPR data are as follows:

- **Average lean percentage (in percent):** Value equal to the average percentage of the carcass weight comprising lean meat.
- **Loin-eye area (in square inches):** The surface area of the Longissimus dorsi muscle at the tenth rib of a pork carcass.
- **Average loin depth (in inches):** Average muscle depth measured between the third and fourth rib from the last rib, 7 cm from the carcass split.
- **Average backfat (in inches):** Average fat thickness measured between the third and fourth rib from the last rib, 7 cm from the carcass split.
- **Average sort loss (in $/cwt carcass weight):** Average discount for hogs slaughtered resulting from the fact that the hogs did not fall within the individual packer's established carcass weight range or lot variation range.
- **Average carcass weight (in pounds):** Weight obtained by dividing the total carcass weight of the hogs slaughtered at the packing plant during the applicable reporting period by the number of hogs.
- **Fat-free lean index:** Index measuring the final carcass fat-free lean as a percentage of the carcass. This index can be calculated and estimated from a fat probe between the third and fourth rib, 7 cm off the midline of the hot carcass. The fat-free lean index is calculated as follows: 51.537 + (0.035 × Carcass, lb) – (12.260 × Backfat, inch).

[2] MPR is available at http://mpr.datamart.ams.usda.gov.

The data used in this analysis are daily observations for the period between August 3, 2001, and September 30, 2005. The summary statistics for seven different quality attributes are reported in Table 4-1. The highest quality hogs typically come from the other purchase arrangements (MA4). This is true for three out of seven quality measurements: the thinnest average backfat (0.7455 inches), the lowest average sort loss (−0.98$/cwt), and the largest fat-free lean index (49.216). The second highest quality hogs come through the other market formula purchases (MA2) that also have three highest quality attributes: the largest loin-eye area (7.36 square in), the thickest average loin depth (2.45 in), and the highest average carcass weight (201.99 lbs). We ranked MA4 ahead of MA2 because MA2 is also associated with the two worst quality attributes (the thickest average backfat of 0.7675 inches and the lowest fat-free lean index of 48.947), while MA4 is never ranked last in any of the considered quality attributes. The only remaining quality attribute is the average lean percent. According to this attribute, the highest ranked marketing arrangement is the swine or pork market formula purchases (MA3) with the highest average lean percent of 54.31%.

Judging by the same seven quality attributes, the lowest quality hogs are recorded in the packer sold category (MA6). In three out of seven quality attributes (average lean percent, loin-eye area, and average loin depth), MA6 ranked last, which seems to indicate that packers typically sell rather than slaughter lower quality hogs.

Next, we test whether the means of a given quality attribute are statistically different across marketing arrangements. We use the *paired observation* procedure, which applies to samples that are not independent and has variances of the two populations that are not necessarily equal. A $(1 - \alpha)$ 100% confidence interval for $\mu_D = \mu_1 - \mu_2$ for paired observations is given by

$$\overline{d} - t_{\frac{\alpha}{2}} \frac{s_d}{\sqrt{n}} < \mu_D < \overline{d} + t_{\frac{\alpha}{2}} \frac{s_d}{\sqrt{n}} \tag{4.1}$$

where $\overline{d}$ and s_D are the mean and standard deviation of the normally distributed differences of n random pairs of measurements, and $t_{\frac{\alpha}{2}}$ is the t-value with $(n - 1)$ degrees of freedom (see Walpole and Myers [1989], p. 254).

Table 4-1. Quality Attributes by Marketing Arrangement in the Hog Sector: Summary Statistics, August 2001–September 2005

Quality Attributes		Marketing Arrangement[a] MA1	MA2	MA3	MA4	MA5	MA6
Average lean percentage	*Sample size*	1,059	1,059	1,059	1,059	1,059	1,055
	Mean	53.38	53.95	54.31	54.09	53.40	53.23
	St. Dev.	0.35	0.36	0.26	0.27	0.34	1.06
	C. V.	0.65	0.66	0.49	0.50	0.63	1.99
Loin-eye area	*Sample size*	1,060	1,060	1,060	1,060	294	1,055
	Mean	6.73	7.36	7.33	6.79	6.66	6.52
	St. Dev.	0.12	0.23	0.12	0.15	0.09	0.36
	C. V.	1.80	3.15	1.68	2.22	1.37	5.47
Average loin depth	*Sample size*	1,060	1,060	1,060	1,060	1,058	1,055
	Mean	2.24	2.45	2.44	2.26	2.22	2.18
	St. Dev.	0.04	0.08	0.04	0.05	0.03	0.12
	C. V.	1.77	3.10	1.65	2.19	1.47	5.37
Average backfat	*Sample size*	1,060	1,060	1,060	1,060	1,058	1,055
	Mean	0.7668	0.7675	0.7474	0.7455	0.7666	0.7535
	St. Dev.	0.02	0.02	0.02	0.02	0.02	0.04
	C. V.	2.78	2.51	2.42	2.06	2.68	5.20
Average sort loss	*Sample size*	1,060	1,060	1,060	1,060	n.a.	992
	Mean	–1.18	–1.04	–1.23	–0.98	n.a.	–1.20
	St. Dev.	0.28	0.30	0.25	0.13	n.a.	0.66
	C. V.	–23.60	–29.21	–20.46	–13.70	n.a.	–54.74
Average carcass weight	*Sample size*	1,060	1,060	1,060	1,059	1,059	1,055
	Mean	194.83	201.99	198.74	198.94	197.32	200.97
	St. Dev.	3.12	3.86	3.20	3.03	3.58	8.00
	C. V.	1.60	1.91	1.61	1.52	1.82	3.98
Fat-free lean index	*Sample size*	1,060	1,060	1,060	1,060	1,058	1,055
	Mean	48.955	48.947	49.193	49.216	48.957	49.118
	St. Dev.	0.29	0.23	0.24	0.21	0.27	0.50
	C. V.	0.59	0.48	0.50	0.42	0.54	1.01

[a] Marketing arrangements are defined as follows:

MA1: Producer-Sold Negotiated
MA2: Producer-Sold Other Market Formula
MA3: Producer-Sold Swine/Pork Market Formula
MA4: Producer-Sold Other Purchase Arrangement
MA5: Packer Owned
MA6: Packer Sold

[b] C. V. = Coefficient of variation

Tables 4-2 through 4-8 present the rankings of the marketing arrangements by their average quality attributes. For example, Table 4-2 presents the ranking of marketing arrangements with respect to average lean percentage. The hogs with the highest average lean percentage of 54.31% came from swine or pork market formula (MA3), followed by the other

Table 4-2. Ranking of Marketing Arrangements by Average Lean Percentage

Average Lean Percentage Decreasing Quality Rank	Mean[a] (%)	Are means pairwise different at α = 0.05?				
		MA4	MA2	MA5	MA1	MA6
1. Swine/pork market formula (MA3)	54.31	Yes	Yes	Yes	Yes	Yes
2. Other purchase arrangement (MA4)	54.09		Yes	Yes	Yes	Yes
3. Other market formula (MA2)	53.95			Yes	Yes	Yes
4. Packer owned (MA5)	53.40				Yes	Yes
5. Negotiated (MA1)	53.38					Yes
6. Packer sold (MA6)	53.23					

[a]Higher mean indicates higher quality.

Table 4-3. Ranking of Marketing Arrangements by Loin-Eye Area

Loin-Eye Area Decreasing Quality Rank	Mean[a] (in^2)	Are means pairwise different at α = 0.05?				
		MA3	MA4	MA1	MA5	MA6
1. Other market formula (MA2)	7.36	Yes	Yes	Yes	Yes	Yes
2. Swine/pork market formula (MA3)	7.33		Yes	Yes	Yes	Yes
3. Other purchase arrangement (MA4)	6.79			Yes	Yes	Yes
4. Negotiated (MA1)	6.73				Yes	Yes
5. Packer owned (MA5)	6.66					Yes
6. Packer sold (MA6)	6.52					

[a]Higher mean indicates higher quality.

Table 4-4. Ranking of Marketing Arrangements by Average Loin Depth

Loin Depth Decreasing Quality Rank	Mean[a] (in)	Are means pairwise different at α = 0.05?				
		MA3	MA4	MA1	MA5	MA6
1. Other market formula (MA2)	2.45	Yes	Yes	Yes	Yes	Yes
2. Swine/pork market formula (MA3)	2.44		Yes	Yes	Yes	Yes
3. Other purchase arrangement (MA4)	2.26			Yes	Yes	Yes
4. Negotiated (MA1)	2.24				Yes	Yes
5. Packer owned (MA5)	2.22					Yes
6. Packer sold (MA6)	2.18					

[a]Higher mean indicates higher quality.

Table 4-5. Ranking of Marketing Arrangements by Average Backfat

Backfat Decreasing Quality Rank	Mean[a] (in)	Are means pairwise different at α = 0.05?				
		MA3	MA6	MA5	MA1	MA2
1. Other purchase arrangement (MA4)	0.7455	Yes	Yes	Yes	Yes	Yes
2. Swine/pork market formula (MA3)	0.7474		Yes	Yes	Yes	Yes
3. Packer sold (MA6)	0.7535			Yes	Yes	Yes
4. Packer owned (MA5)	0.7666				No	No
5. Negotiated (MA1)	0.7668					No
6. Other market formula (MA2)	0.7675					

[a]Higher mean indicates higher quality.

Table 4-6. Ranking of Marketing Arrangements by Average Sort Loss

Sort Loss Decreasing Quality Rank	Mean[a] ($/cwt)	Are means pairwise different at α = 0.05?				
		MA2	MA1	MA6	MA3	MA5
1. Other purchase arrangement (MA4)	–0.98	Yes	Yes	Yes	Yes	NA
2. Other market formula (MA2)	–1.04		Yes	Yes	Yes	NA
3. Negotiated (MA1)	–1.18			No	Yes	NA
4. Packer sold (MA6)	–1.20				No	NA
5. Swine/pork market formula (MA3)	–1.23					NA
6. Packer owned (MA5)	NA					

[a]Lower mean indicates higher quality.
NA = Not available

Table 4-7. Ranking of Marketing Arrangements by Average Carcass Weight

Carcass Weight Decreasing Quality Rank	Mean[a] (lb)	Are means pairwise different at α = 0.05?				
		MA6	MA4	MA3	MA5	MA1
1. Other market formula (MA2)	201.99	Yes	Yes	Yes	Yes	Yes
2. Packer sold (MA6)	200.97		Yes	Yes	Yes	Yes
3. Other purchase arrangement (MA4)	198.94			Yes	Yes	Yes
4. Swine/pork market formula (MA3)	198.74				Yes	Yes
5. Packer owned (MA5)	197.32					Yes
6. Negotiated (MA1)	194.83					

[a]Higher mean indicates higher quality.

Table 4-8. Ranking of Marketing Arrangements by Fat-Free Lean Index

Fat-Free Lean Index Decreasing Quality Rank	Mean[a]	Are means pairwise different at $\alpha = 0.05$?				
		MA3	MA6	MA5	MA1	MA2
1. Other purchase arrangement (MA4)	49.22	Yes	Yes	Yes	Yes	Yes
2. Swine/pork market formula (MA3)	49.19		Yes	Yes	Yes	Yes
3. Packer sold (MA6)	49.12			Yes	Yes	Yes
4. Packer owned (MA5)	48.96				No	No
5. Negotiated (MA1)	48.96					No
6. Other market formula (MA2)	48.95					

[a]Higher mean indicates higher quality.

purchase arrangement (MA4). In the right-hand side panel of the table, we test whether quality means are pairwise different across marketing arrangements at the 5% confidence interval. As the results suggest, almost all lean percentage means are different from each other. Testing for the pairwise differences across means produced similar results for other quality attributes. Most of the means are statistically significantly different from each other.[3]

Finally, the actual measurements of the daily fluctuations in various quality attributes of the best and the worst marketing arrangements are graphed in Figures 4-1 through 4-8. For example, in Figure 4-3 the data exhibit a fairly large difference in loin depths between the best and the worst marketing arrangement (in this case other market formula and packer sold), whereas in Figure 4-4, one sees that the difference between the best and the worst marketing arrangement (in this case, other purchase arrangements and other market formula) in terms of backfat is rather small.

4.2 QUALITY MEASUREMENT USING HICKS' COMPOSITE COMMODITY INDEX

In this section, we use national MPR data for current volumes by purchase type (daily observations on head count, barrows

[3] The loin-eye area pairwise difference of any channel with the *packer owned* channel is calculated based on the smaller sample because the packer owned data have a lot of missing values for loin-eye area.

Figure 4-1. Average Lean Percentage, January 2002–September 2005

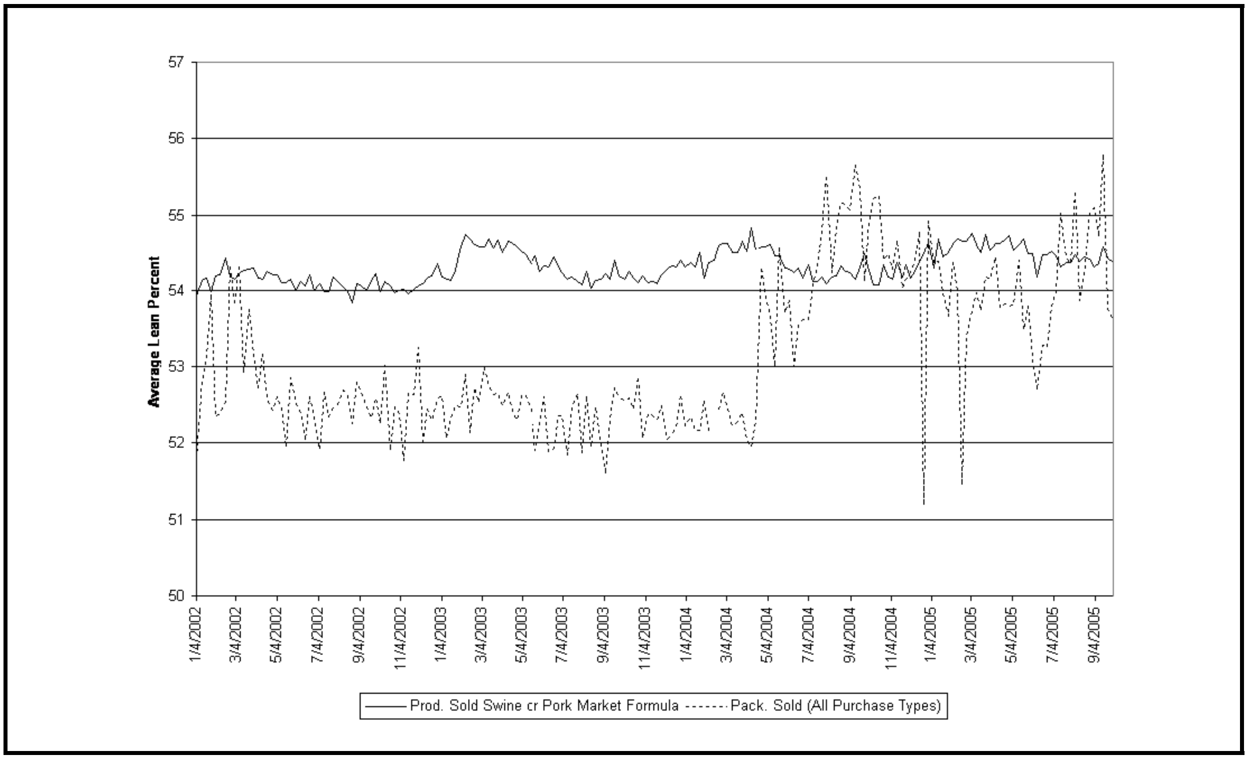


Figure 4-2. Loin-Eye Area, January 2002–September 2005

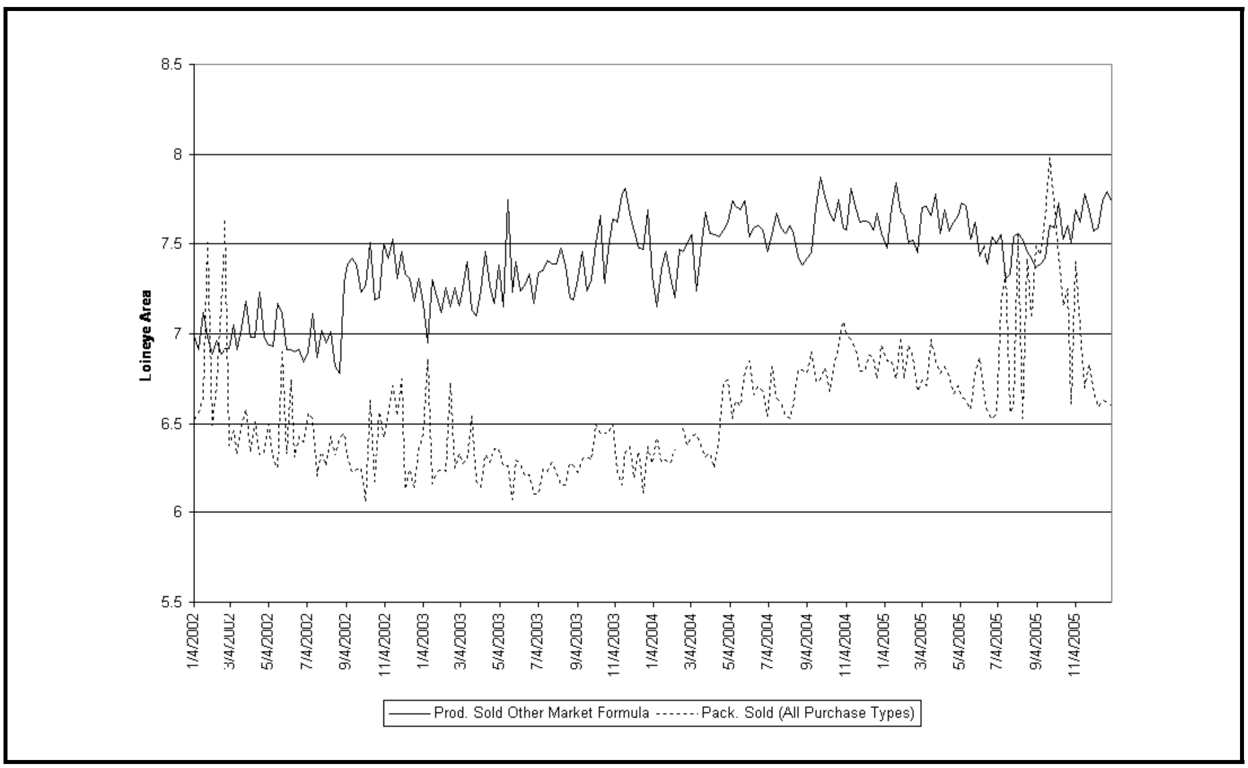


Figure 4-3. Average Loin Depth, January 2002–September 2005

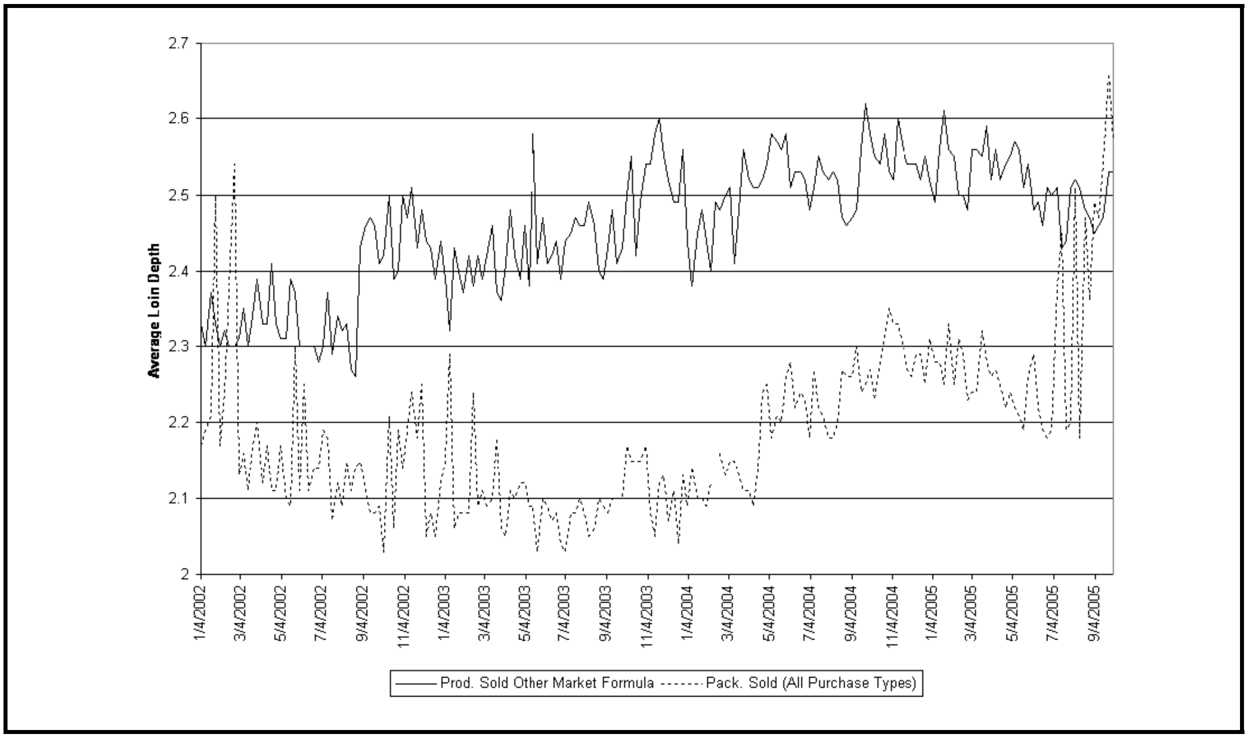


Figure 4-4. Average Backfat, January 2002–September 2005

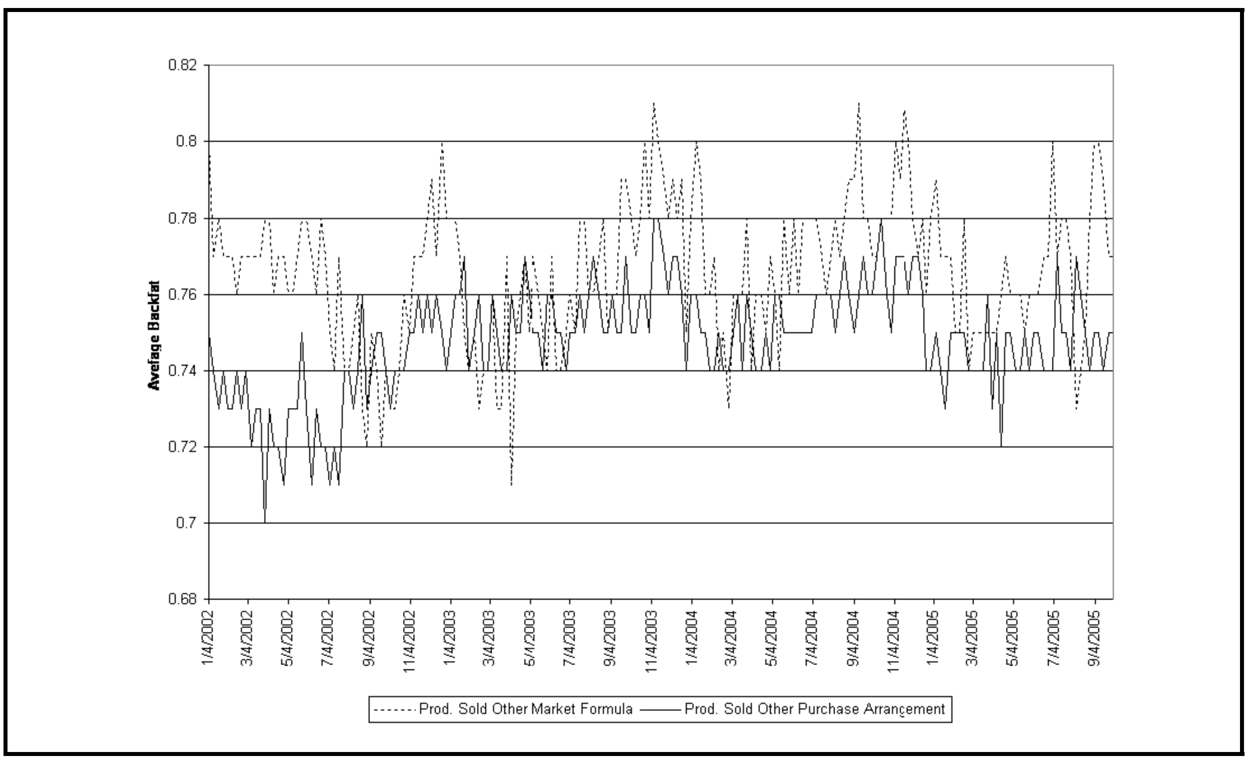


Figure 4-5. Average Sort Loss, January 2002–September 2005

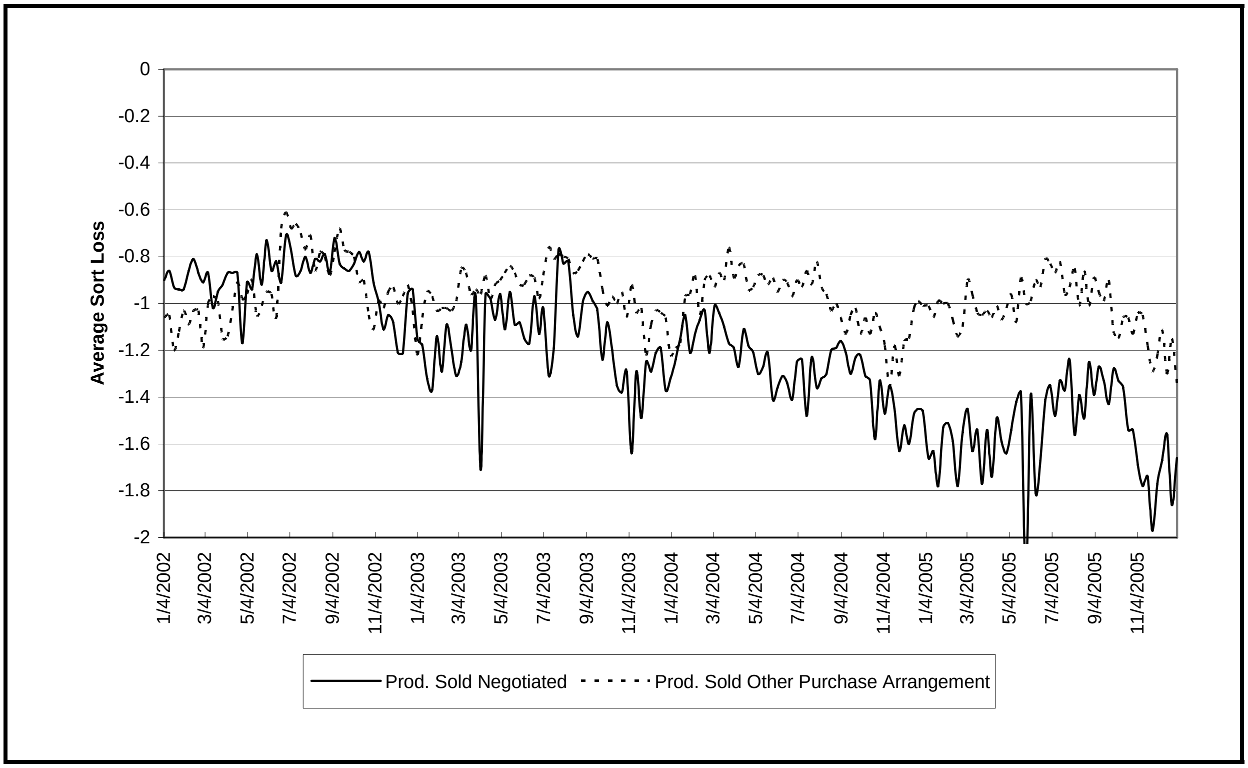


Figure 4-6. Average Carcass Weight, January 2002–September 2005

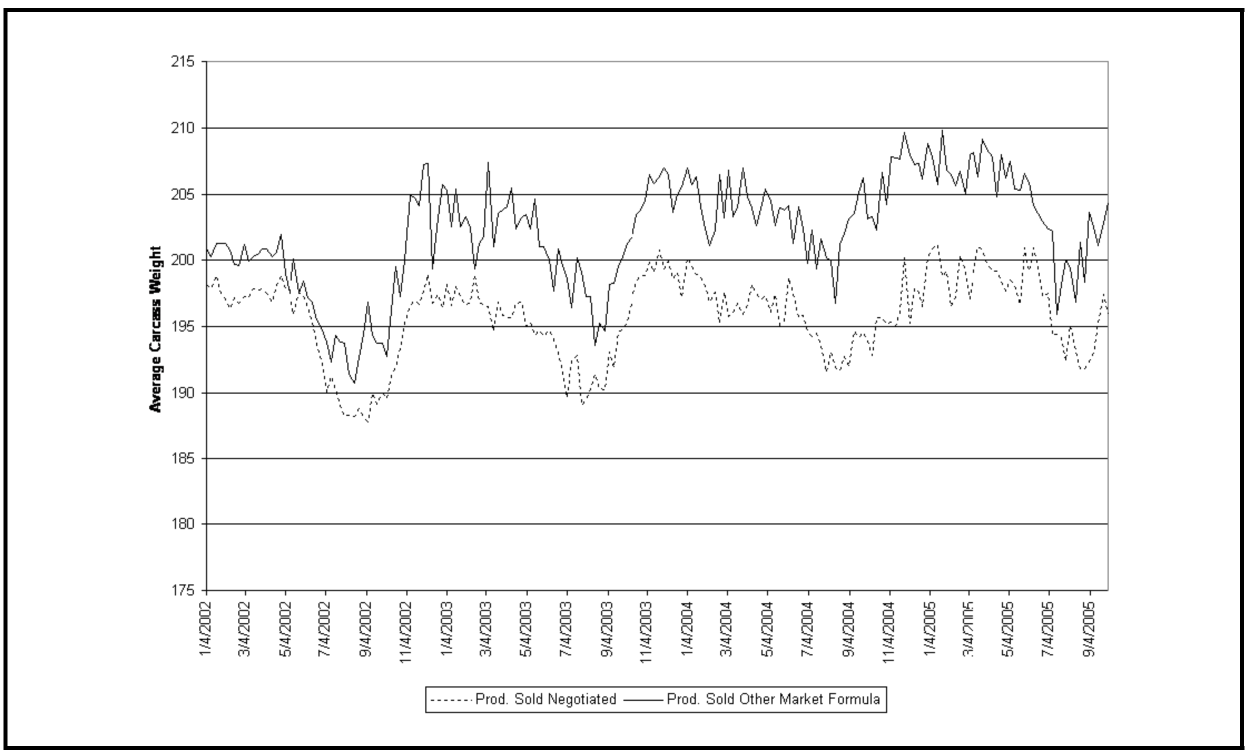


Figure 4-7. Fat-Free Lean Index, January 2002–September 2005

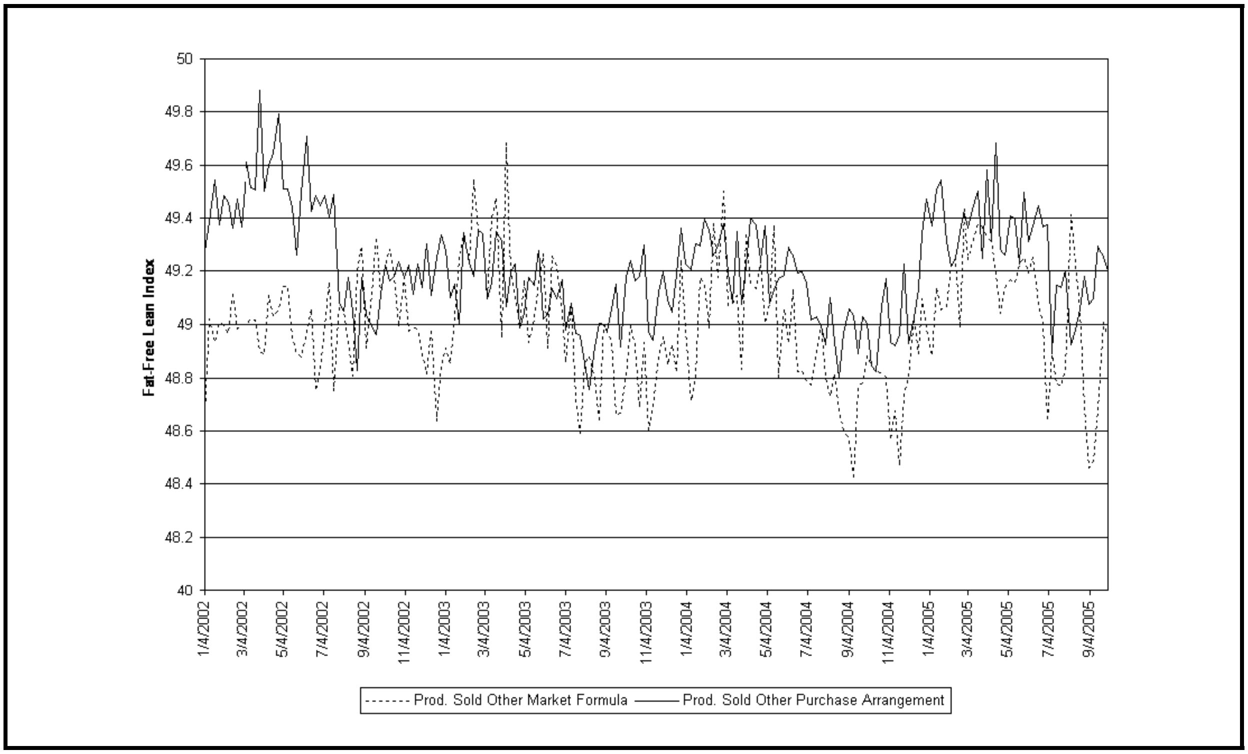
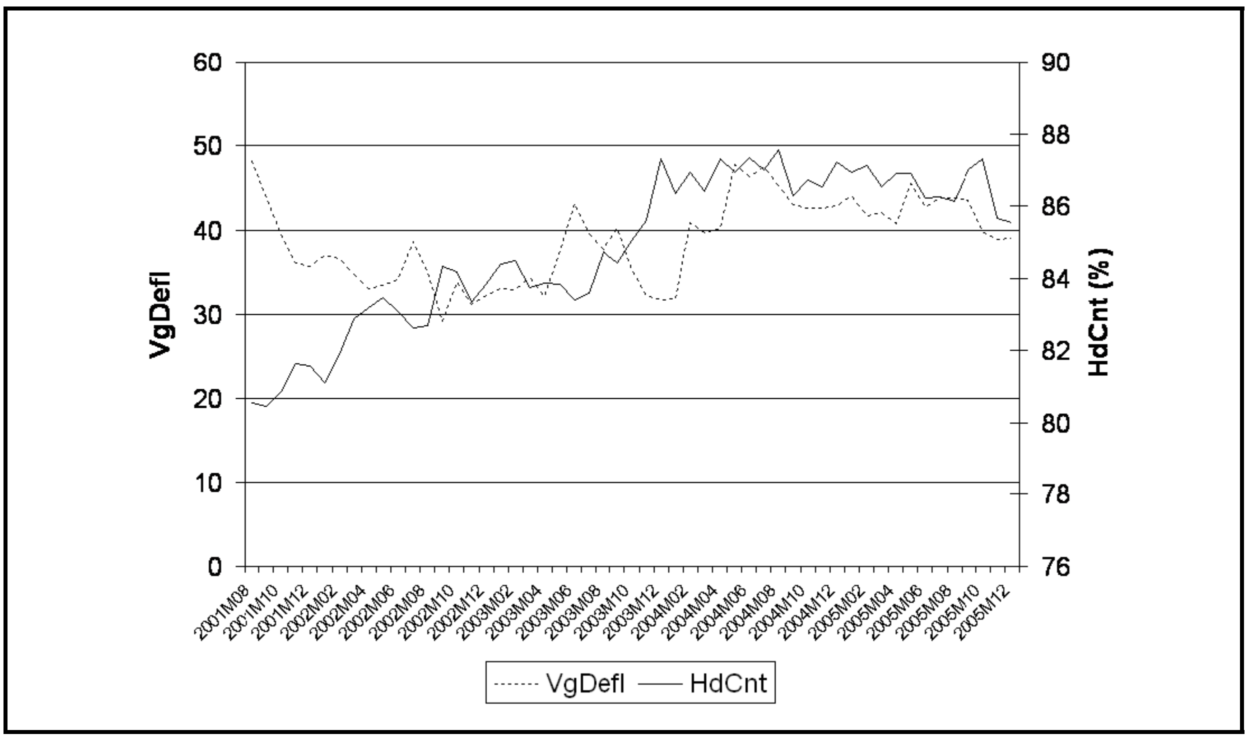


Figure 4-8. *VgDefl* and *HdCnt*, January 2002–September 2005



VgDefl = pork quality index using Hicks' composite commodity formula
HdCnt = percentage of AMAs

and gilts)[4] and pork carcass cut-out (weekly observations on primal values and load counts for the August 3, 2001, to September 30, 2005 period).[5] The data have been aggregated into 50 monthly observations by calculating monthly sums of quantity variables and monthly simple averages of primal cuts values. The values of various pork cuts are deflated using the consumer price index for pork (1982–84 = 100).[6]

First, we construct the average quality index based on Hicks' composite commodity formula (Theil, 1952–1953; Cramer, 1973; and Nelson, 1991. This quality index is formulated as

$$V_G = \frac{\sum_{i \in G} p_i x_i}{q_G}, \tag{4.2}$$

where x_i are the quantities of elementary goods (various pork cuts: loin, butt, picnic, rib, ham, belly) that belong to the same commodity group G, p_i are the prices of various pork cuts, and $q_G = \sum_{i \in G} x_i$ is the heterogeneous commodity group (pork meat). Based on this measure, the larger the proportions of higher priced cuts in the total sales bundle, the higher the measure of quality. Measuring quality associated with different AMAs would ideally require that the sales data contain some indicator of the marketing arrangement used to get this product to the market. However, even if sales data do not include AMA indicators, one can still calculate aggregate V_G as described above and then look at the composition of AMAs for the upstream segment. This will give us some indication of the pork quality differences caused by different combinations of upstream AMAs.

To implement this method, we calculated the percentage share of all marketing arrangements other than negotiated purchases (MA1) and packer sold (MA6) in the total volume of live animals purchased. The variable is constructed as the ratio between (other market formula purchases + swine/pork market formula purchases + other purchase arrangement + packer owned) and total purchases, where the total purchases contain all of the above methods plus negotiated (spot) purchases and packer

[4] These observations are available at the MPR Datamart Web site (http://mpr.datamart.ams.usda.gov).

[5] These observations were obtained from various issues of USDA National Meat Trade Review (http://www.ams.usda.gov/LSMNpubs/PDFMonthly/composite.htm).

[6] These data were obtained from the Bureau of Labor Statistics Web site (http://www.bls.gov).

sold. The prediction here is that all AMAs should on average enable packers to acquire higher quality hogs (and hence produce higher quality pork) than those acquired on an open negotiated (spot) market or via the packer sold channel.

The time plot of both series is presented in Figure 4-8. As the figure shows, the percentage of AMA purchases (HdCnt) exhibits a time trend, while the pork quality index (VgDefl) does not. Also, in two subsample periods—August 2001 to September 2002 and March 2003 to December 2003—the two series are moving in the opposite direction. Because our purpose is to examine the qualitative relationship between the two time series, we then calculated the correlation coefficient. The estimated sample correlation coefficient between the two series is 0.3661, with a 95% confidence interval of (0.098, 0.5849). Therefore, we reject the null hypothesis of no correlation between the pork quality and the share of AMAs in the total market hog purchases at the 5% significance level.[7] Based on this result, we conclude that more hogs are purchased through AMAs, thus translating into higher quality pork products that can be sold on the meat market.

4.3 SUMMARY

This section analyzes quality differences in live market hogs across alternative procurement methods. First, we tested if various quality attributes used by the industry are signi•cantly different across marketing arrangements. Test results indicate that different marketing arrangements yield different quality hogs. Even though the rankings are not unique, we found that marketing contracts (especially other purchase arrangements and other market formula purchases) consistently yield higher quality hogs than negotiated (spot) purchases.

Second, we examined the relationship between the proportion of the higher level procurement methods in the total acquisition of live market hogs and the quality of resulting pork products. We measured pork quality by Hicks' composite commodity index and assumed that a higher percentage share of the AMAs (essentially marketing contracts and packer-owned hogs) should produce higher quality pork products. The correlation coefficient showed that these two series are positively correlated, confirming our hypothesis.

[7] The t-test statistic (2.726) is greater than the critical value (2.01).

5 Risk Shifting Associated with Alternative Marketing Arrangements

In this section, we address the issue of risk allocation among various economic agents (farmers, integrators, packers) involved in the hog industry. The standard assumption in the industrial economics literature is that firms are risk neutral. This is especially the case for publicly traded firms that can diversify risk by spreading it among a large number of shareholders. On the other side of the hog industry, there is a large number of farmers who are generally ill equipped to bear risk and therefore frequently seek various avenues to reduce their risk exposure. Hog farmers are concerned with several types of risk. The most important is price risk (both on the input side as well as on the output side), followed by various types of production risks (common and idiosyncratic), and finally market access risk. In this context, the type of risk shifting that needs to be analyzed is the transfer of risk from risk-averse farmers to risk-neutral (or less risk-averse) integrators or packers.

The mechanisms through which this risk shifting occurs include AMAs. Various types of marketing arrangements are associated with different levels of risk, and they can transfer different components of the total risk from the producer/farmer to the contractor (packer or integrator). Production contracts usually eliminate the entire price risk, as well as the market access risk, from the responsibility of the producer. In cases where the payment is based on the relative performance (tournaments), production contracts eliminate the common production risk as well, such that the only risk left is the producer's own individual, or idiosyncratic, risk. In cases where the payment is based on the absolute performance (say feed conversion brackets), production contracts do not eliminate the common production shock. Marketing contracts generally eliminate market access risk, could sometimes eliminate some of the price risk, but would generally not eliminate production risk. Finally cash or spot market sales expose the producer to all types of risk associated with hog production.

The analysis of risk shifting in this section proceeds in three directions. First, we measure the variances of payments received by producers selling their hogs through different marketing channels, and we test whether the pairwise differences among those variances are statistically significant. Next, because of the inability to obtain sufficient data on production contract settlements through the data collection procedures for this study, we instead extracted some of the relevant results on risk shifting from the existing literature (Martin, 1994). Finally, using Agricultural Resource Management Survey (ARMS) data, we were able to estimate the risk-aversion parameters for different groups of producers; based on these estimates we performed a counterfactual simulation to measure the extent of the utility associated with forcing farmers out of their risk-aversion-preferred marketing arrangement choice.

5.1 RISK REDUCTION THROUGH MARKETING ARRANGEMENTS

For the analysis of risk reduction between marketing arrangements and cash market sales, we used *USDA/AMS Mandatory Price Reports* (hereafter, MPR).[1] As described in Section 2, the marketing channels are Negotiated Purchases (MA1), Other Market Formula Purchases (MA2), Swine or Pork Market Formula Purchases (MA3), Other Purchase Arrangements (MA4), Packer Owned (MA5), and Packer Sold (MA6). Because we are interested in comparing the volatilities in the marketing contracts channels against the spot/cash

[1] MPR is available at http://mpr.datamart.ams.usda.gov.

market, we exclude MA5 and MA6 because these two arrangements likely include production contracts and packer-owned farms.

Assuming that the variance of the price through each arrangement over time represents the risk of that particular arrangement, we compiled the daily average net prices of each arrangement over the period of August 3, 2001, through March 27, 2006, and conducted a pairwise test of equal variance. The prices are base prices for barrows and gilts, carcass basis expressed in $/cwt. Greater variance of payments indicates higher risk (see Table 5-1).

Table 5-1. Variance-Covariance Matrix of Hog Prices, by Marketing Channel

Marketing Channel	MA1	MA2	MA3	MA4
MA1[a]	132.89	71.64	126.13	75.63
MA2[b]		52.71	68.03	39.52
MA3[c]			120.18	72.37
MA4[d]				47.78

[a] MA1: Negotiated purchases
[b] MA2: Other market formula purchases
[c] MA3: Swine/hogs market formula purchases
[d] MA4: Other purchase agreements

Based on the computed variances (main diagonal elements in Table 5-1), we ordered the marketing arrangements according to the magnitude of risk they carry: MA1, MA3, MA2, and MA4. This order is quite intuitive: MA1 is spot/cash market sales, which should obviously have the greatest risk; MA3 is marketing contracts whose pricing formula is based on different spot markets; MA2 is another type of marketing arrangement for which the pricing formula is based on some futures or options price; and MA4 contains ledgers, windows, and other pricing mechanisms, which all serve to moderate price volatility.

To test the null hypothesis that the variances of the payments are identical under two different types of arrangements, we can use the asymptotic Wald test proposed by Knoeber and Thurman (1995). The test statistic is given by

$$T = \frac{s_1^2 - s_2^2}{\left[\frac{2}{n}(s_1^4 + s_2^4 - 2s_{12}^2)\right]^{1/2}}\ , \qquad (5.1)$$

where s_1^2 and s_2^2 are the sample variances for two different payment time series and s_{12} is the sample covariance. Under the null, T is asymptotically standard normal. This test is needed when the two price series of interest are statistically dependent on each other (otherwise, a standard F-test could be used for testing the equal variances).

For different combinations of i and j, the null and alternative hypotheses are given as

$$\begin{aligned} H_0 &: \ Var(\text{price of MA}_i) = Var(\text{price of MA}_j) \\ H_1 &: \ Var(\text{price of MA}_i) > Var(\text{price of MA}_j). \end{aligned} \qquad (5.2)$$

The results are summarized in Table 5-2.

Table 5-2. Tests for Risk Reduction: Cash Sales and AMAs

Tests[a]	Wald Test Statistic	p value
MA1[b] vs. MA2[c]	19.37	.000
MA1 vs. MA3[d]	18.42	.000
MA1 vs. MA4[e]	22.49	.000
MA3 vs. MA2	18.42	.000
MA3 vs. MA4	22.31	.000
MA2 vs. MA4	2.73	.003

[a] Test (MA_i vs. MA_j) hypotheses are
H_0 : $Var(\text{price of MA}_i) = Var(\text{price of MA}_j)$
H_1 : $Var(\text{price of MA}_i) > Var(\text{price of MA}_j)$

[b] MA1: Negotiated purchases

[c] MA2: Other market formula purchases

[d] MA3: Swine/hogs market formula purchases

[e] MA4: Other purchase agreements

The results indicate that all null hypotheses were rejected at 1% level of significance. The pairwise testing of the differences in prices across various marketing arrangements thus confirmed that all price variances are statistically different from each other. Therefore, we conclude that the magnitude of risk that hog producers are exposed to varies with the marketing arrangements through which hogs are transacted.

5.2 RISK REDUCTION THROUGH PRODUCTION CONTRACTS

Martin (1994) conducted an analysis of risk reduction in the hog industry when production contracts are employed. The data came from a North Carolina integrator and cover the period between September 1985 and December 1992. The data set contains 805 observations on individual contract settlements of 123 contract growers. The number of observations per farmer (i.e., herds or groups per grower) varies from 2 to 37 with a mean of 6.5 observations. This data set is rather old but still relevant because the actual payment mechanisms used in hog finishing contracts have not changed much since production contracts were originally introduced. To the best of our knowledge, this is the only detailed hog production contracts settlement data in the public domain.

In a finishing contract, the compensation to the grower i for the batch of hogs under contract t is paid on a per-pound of gain basis with bonuses earned on a per-head basis. Bonuses are paid only to the farmers whose feed conversion ratio (pounds of feed divided by pounds of gain, $\frac{F_{it}}{g_{it}}$) is less than a standard feed conversion ratio (denoted by ϕ). If the grower's ratio is below the standard ratio, the difference is multiplied by a constant ζ to determine the per-head bonus measure. This number is multiplied by the total heads shipped (Q_{it}) to obtain the total bonus. Otherwise, the growers will receive no bonus. Regardless of their performances, all growers earn the piece–rate, ξ, multiplied by the total pounds gained, g_{it}. Now, compensation under a production contract can be mathematically expressed as

$$P_2 = \xi g_{it} + \max\left[0, \varsigma\left(\phi - \frac{F_{it}}{g_{it}}\right)\right]Q_{it} \ . \tag{5.3}$$

Note that this payment is based on the absolute performance and contains both idiosyncratic and common production shocks, but price shock risk is completely eliminated because neither the prices of inputs (corn, soybeans) nor the price of output (live hogs) enters the payment formula.

To see if contract farmers face less risk than independent farmers, we simulated the payments to the independent farmers (P_1).[2] Risk reduction then is analyzed by conducting a test for the null hypotheses of equal variances of two payment series, P_2 and P_1. The test can be described as follows:

$$H_0 : \sigma^2_{P_1} = \sigma^2_{P_2} \qquad (5.4)$$
$$H_1 : \sigma^2_{P_1} > \sigma^2_{P_2} \ ,$$

where $\sigma^2_{P_2}$ is the variance of the actual production contract payment and $\sigma^2_{P_1}$ is the variance of the simulated spot market payment. Because 123 farmers in the sample are heterogeneous, this test is performed for each farmer. Because contract payments (P_2) and the constructed market payments (P_1) are not statistically independent of each other, the conventional F–test is not applicable. Hence, the asymptotic Wald test described in Eq. (5.1) is used. When contract farmers are compared with independent hog–finishing farmers, the null of equal variances is rejected for 74% of the farmers. The null hypothesis is not rejected only for those farmers with small number of observations (contract settlements). Because applying the asymptotic Wald test in Eq. (5.1) in small samples might be misleading anyway, the evidence for risk reduction via production contracts relative to spot markets is overwhelming.

Next, we decompose the variance of grower income into production shock (ϵ_Q) and price variability (ϵ_P). The payments to contract farmers (P_2) and independent farmers (P_1) can be expressed as

$$P_2 = \mu_2 + \epsilon_Q \qquad (5.5)$$
$$P_1 = \mu_1 + \epsilon_Q + \epsilon_p \ .$$

In matrix form, Eq. (5.5) can be rewritten as $P = \mu + \omega\epsilon$, where P, μ, and ϵ are (2 × 1) vectors and $\omega = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix}$. Using

[2] The assumption was that independent farmers buy all their inputs on an open market and sell their hogs on a cash/spot market. For the details of the simulation, see Martin (1994, Section 6.1, pp. 55–59).

the covariance matrix of observable payment series (V_P), the covariance matrix of unobservable shocks (V_ϵ) can be recovered as follows:

$$V_\epsilon = \omega^{-1} V_P (\omega^{-1})' = \begin{bmatrix} \sigma_Q & \sigma_{QP} \\ \sigma_{PQ} & \sigma_P^2 \end{bmatrix}. \qquad (5.6)$$

Assuming that the maximum income variability is the same as the income variability associated with the cash/spot marketing of hogs, the total risk measured by the variance of cash/spot market payments (V_{P_1}) can be decomposed as

$$V_{P_1} = Var(\epsilon_Q + \epsilon_P) = \sigma_Q^2 + \sigma_P^2 + 2\sigma_{QP} \qquad (5.7)$$

and the relative importance of the three risk components can be calculated as

$$\alpha_Q = \frac{\sigma_Q^2}{V_{P_1}}, \quad \alpha_P = \frac{\sigma_P^2}{V_{P_1}}, \quad \alpha_{QP} = \frac{2\sigma_{QP}}{V_{P_1}}. \qquad (5.8)$$

Based on Martin's (1994) results with 77 farmers who have five or more observations, we obtain the following decomposition results. Price shocks, which get completely eliminated from the contract payment, are the largest source of risk and represent about 94.17% of the total income variability. The pure contribution of production shocks is relatively small at 1.78% of the total variation. The interactive effect from the production and price shocks represents about 4.05% of the total variability. Hence, one can conclude that production contracts would eliminate about 94% of the total income variability to which an independent farmer selling hogs on the spot market would be exposed.

5.3 FARMERS' RISK AVERSION AND CONSEQUENCES FOR CONTRACT CHOICE

In this section, we model the decision process of a risk-averse hog farmer who must decide whether he wants to be an independent producer or a contract operator and then, conditional on the choice of marketing arrangement, decide how many hogs to produce.[3]

[3] Our approach is reminiscent of the models used in the health insurance literature, see for example Bajari, Hong, and Khwaja (2005), where an individual first decides which health plan to purchase and then conditional on the choice of health plan and the

5.3.1 Model Specification

We use this model as the basis for analyzing the relationship between contract choice and risk tolerance. Without any loss of generality, we assume that there are only two time periods. In the first time period, farmers face a menu of choices from a set of available marketing arrangements that depends on the location of the farm. In some states/regions, farmers can choose between cash/marketing arrangements and production contracts; in other regions, production contracts may not be available because no packers or integrators offer them. Each farmer forms expectations about the profits he will earn in different marketing arrangements and, given his choice set, chooses a marketing arrangement $d \in D$ that maximizes his utility of profits from hog production that will occur in the second period. Formally, this can be represented as follows:

$$\max_{d \in D}(V_1, \ldots, V_D),$$

$$\text{with } V_d = E_{t=1}U_d(\pi^{d*}) \tag{5.9}$$

where V_d is the expected utility (expectations formed in the first period) of the second period profit $\pi^{d*} = R^{d*} - C^{d*}$ associated with the optimal production decision q^{d*}.[4]

In the second period, conditional on the chosen marketing arrangement, and after learning his price or contract payment and his costs, each farmer makes a decision about the production level q that will maximize his utility. Formally we assume that the farmer's utility function is given by

$$U(R(q), C(q), \gamma)$$
$$= U(R(q), \gamma_1) - \gamma_3 U(C(q), \gamma_2) \;. \tag{5.10}$$

where the parameter vector $\gamma = (\gamma_1, \gamma_2, \gamma_3)$ is additively separable in the revenue of production $R(q)$ and the cost of production $C(q)$. This assumption implies that a farmer's risk

observed state of her own health, decides how much health care to purchase.

[4] Our theoretical model allows the first stage choice of marketing arrangements; however, in our empirical analysis we do not estimate the first stage model for two reasons. First, the procedure for structural estimation of the two-stage model is quite involved, see Cardon and Hendel (2001), and outside the scope of this project. Second, the price data on the farmers' choice sets and outside opportunities would be difficult to assemble.

aversion could vary differently with revenue through parameter γ_1 than with costs through a different parameter γ_2 and could also carry different weights for the two utilities through γ_3.[5] This generality is important in this particular context because the producer's revenue is always expressed in monetary units, whereas the cost of production could be a combination of monetary (money used to buy inputs) and nonmonetary costs (e.g., operator's own or his family members' effort exerted to manage the farm efficiently). Therefore, it is conceivable that the utilities associated with two components of the profit function may take different forms.

To solve the maximization problem, we further assume that the utility function of the revenue side exhibits constant relative risk-aversion (CRRA) preference structure

$$U(R(q),\gamma_1) = (pq)^{\gamma_1} \tag{5.11}$$

with parameter $0 < \gamma_1 < 1$, and that the disutility of costs can be adequately represented by the following reduced-form specification

$$\gamma_3 U(C(q),\gamma_2) = \alpha_0 + \alpha_1 q + \frac{\alpha_2}{2}q^2 + \varepsilon q, \quad \alpha_2 > 0 \tag{5.12}$$

where ε captures the unobserved (to the econometrician) heterogeneity in farmers' disutilities of production costs.[6]

With these specifications, the maximization problem for a farmer using marketing arrangement *d* can be written as

[5] This specification, which is fairly common in the information economics literature (see, for example, Bajari, Hong, and Khwaja [2005]), ensures that the risk aversion parameter(s) does not drop out from the first order condition for utility maximization. This would render the first order conditions under risk aversion empirically indistinguishable from the risk neutral case. The ability to estimate the risk aversion parameters is an important part of our estimation strategy, as we show later.

[6] Alternatively, one can specify $\gamma_3 U(C(q), \gamma_2)$ as $\gamma_3 (C(q))^{\gamma_2}$ and then use the same reduced-form specification for $C(q)$ like $C(q) = \beta_0 + \beta_1 q + \frac{\beta_2}{2}q^2 + \varepsilon q$. The advantage of this specification is that it enables the recovery of the cost function and the risk aversion parameters γ_2 and γ_3. However, the problem is that the second order condition for maximum is not guaranteed. We estimated this model and found that for about 30% of observations, the second order condition is violated.

$$\max_{q^d} = \left(p^d q^d\right)^{\gamma_1^d} - \alpha_0^d - \alpha_1^d\, q^d - \frac{\alpha_2^d}{2}(q^d)^2 - \varepsilon^d q^d \ , \quad (5.13)$$

where the superscript *d* is used to denote the different sets of parameters in different marketing arrangements. The implied first order condition is

$$\gamma_1^d \left(p^d q^{d*}\right)^{\gamma_1^d - 1} p^d - \alpha_1^d - \alpha_2^d q^{d*} - \varepsilon^d = 0 \ . \quad (5.14)$$

We use Eq. (5.14) as the basis for developing our estimation strategy below.

5.3.2 Model Estimation

In the econometric investigation adopted in this section, the statistical inference is based on the assumption that the number of farmers approaches infinity. Therefore, possible farmers' heterogeneity needs to be taken into account. This issue can be addressed by modeling disutilities of costs to depend on farmers' socioeconomic characteristics. Specifically, let farmers be indexed by (i = 1,..., N^d) where N^d denotes the number of farmers in the data set using marketing arrangement *d*, and specify

$$\alpha_{1i}^d = x_i \phi^d \quad (5.15)$$

where x_i is a vector of variables characterizing the observed heterogeneity for farmer *i*. Also, let's assume that the unobserved heterogeneity (to the analyst) in the disutility of production costs ε_i^d is normally distributed with mean 0 and variance $\left(\sigma_\varepsilon^d\right)^2$.

The first order condition Eq. (5.14) can be rewritten as

$$\varepsilon_i^d = \gamma_1^d \left(p_i^d q_i^{d*}\right)^{\gamma_1^d - 1} p_i^d - \alpha_{1i}^d - \alpha_2^d q_i^{d*} \quad (5.16)$$

where p_i^d is the price per live hog received by farmer *i* and q_i^{d*} is his optimal production-level decision. Hence, the likelihood function for the sample of farmers using marketing arrangement *d* can be written as

$$L = \prod_{i=1}^{N^d} f\left(\varepsilon_i^d \mid \gamma_1^d,\ \phi^d,\ \alpha_2^d,\ \left(\sigma_\varepsilon^d\right)^2\right) \left| \frac{\partial \varepsilon_i^d}{\partial q_i^d} \right| \quad (5.17)$$

where $f(\cdot)$ is the normal density and

$\left| \frac{\partial \varepsilon_i^d}{\partial \mathrm{q}_i^d} \right| = \left| \gamma_1^d \left(\gamma_1^d - 1\right)\left(p_i^d q_i^{d*}\right)^{\gamma_1^d - 2} \left(p_i^d\right)^2 \right|$ is the Jacobian part of the derived likelihood. The purpose of the estimation is to recover the model primitives, that is, the farmers' risk aversion parameter, the cost function parameters, and the distribution of the unobserved heterogeneity. More specifically, we must estimate the parameter vector $\Delta = \left(\gamma_1^d, \phi^d, \alpha_2^d, \left(\sigma_\varepsilon^d\right)^2\right)$ from the data on individual hog farmer's production-level choices. The estimation method used is maximum likelihood.

To assess how our specification fits the data, we performed a formal statistical model selection test against an alternative specification. Here, using the same reduced form specification for the cost function, we consider the case of a risk-neutral farmer whose maximization problem can be written as

$$\max_q \quad pq - C(q)$$

$$= \max_q \quad pq - \lambda_0 \quad \lambda_1 q \ \frac{\lambda_2}{2} q^2 - \epsilon q. \qquad (5.18)$$

This specification is a special case of our model with $\gamma = 1$. It is also empirically indistinguishable from the specification $(pq - C(q))^{\gamma}$ because the two have the same first order conditions. As we show in the next section, the data reject this specification in favor of Eq. (5.13).

5.3.3 Estimation Results

We estimated the model using ARMS data for 2004. The details about the data set are presented in Appendix C, and the estimation results are summarized in Table 5-3. We estimated two models: one with the subsample of farmers who are using the cash/marketing arrangements and another with the subsample of farmers who are using production contracts. As mentioned in Appendix C, to account for possible systematic differences across farmers, we choose x = {cons, farmtype, farmsize, east, midwest, offincome, age, educ, nfamily, nfasset}. The log likelihood at convergence is positive because at the estimated parameter values, the log of the Jacobian part of the likelihood function Eq. (5.17) is positive. Several estimation results are worth emphasizing.

Table 5-3. Estimation Results for the Risk and Contract Choice Model

	Cash/Marketing Arrangements		Production Contracts	
Variable	**Estimate**	**t-stat**	**Estimate**	**t-stat**
constant	81.0420	9.4151	6.2387	4.6690
farmtype	–14.6510	–10.8580	–2.4581	–4.8477
farm acreage	–2.1846	–7.5809	–0.3879	–4.2154
east location	9.0361	3.2341	–1.1372	–2.2441
midwest location	–0.8324	–0.3766	0.3891	0.7161
off farm income	1.0520	11.6200	0.1208	3.3841
age	1.9903	2.1857	0.0327	0.1969
education	0.4190	0.4601	–0.4685	–2.1385
number family members	–0.2258	–0.4909	0.0563	0.4188
nonfarm assets	–0.9473	–3.8243	–0.0517	–0.9903
α_2	2.9910	4.9307	1.5669	6.5526
σ_ε^2	541.9300	13.5360	5.4501	5.6229
γ_1	0.8187	88.7710	0.5047	14.0090
Log likelihood	629.6880		85.9631	
Number of Observations	457		279	

First, whether the hog operation is the main enterprise on the farm has a significant negative effect on the marginal disutility of production costs, both for cash/marketing farmers and for production contract farmers. This indicates that farms can achieve economic efficiency by specialization. For example, the marginal disutility of production costs is lower by 14.65 utility units for a cash/marketing farmer with specialization in hogs compared with a farmer who does not specialize.

Second, the farm size also has a significant negative effect on the marginal disutility of production costs, both for cash/marketing farmers and for production contract farmers. This indicates that there are returns to scale in hog production. For example, the marginal disutility of costs for a production contract farmer decreases by 0.39 units when the log of his farm acreage increases by 1.

Third, interestingly, the geographic location also affects the farmer's marginal disutility of production costs. Specifically, if a farmer who uses cash/marketing arrangements is located in the East, which includes North Carolina, Virginia, and Georgia, all of which have a limited tradition in hog farming, his marginal disutility is significantly higher compared with the farmers in other regions. However, for a contract operator in the East, which includes North Carolina, the cradle of production contracts, the marginal disutility of production costs is significantly lower compared with farmers in other regions.

Next, the more off-farm income the farmer has, the higher his marginal disutility of producing hogs, whether or not he uses cash/marketing arrangements or production contracts. Having higher off-farm income means having better opportunities for earning income outside of agricultural production.

Also, age has a significant positive effect on the farmer's marginal disutility of production costs if he uses cash/marketing arrangements, but age does not have a significant effect if the farmer is a contract producer. Using this result, we predict a growing popularity of production contracts relative to independent livestock production as the farming population grows older. On the other hand, whether a farmer/operator has at least some college education does not have a significant effect on his marginal disutility of production costs if he uses cash/marketing arrangements but has a significant negative effect if the farmer/operator uses production contracts. Perhaps farmers who have some college education are capable of better understanding contract terms, especially the payment mechanisms, which sometimes can be fairly complicated, and take advantage of the process much better than less educated people.

Finally, the risk adverse parameter γ_1 is estimated to be 0.8187 for farmers who use cash/marketing arrangements and 0.5047 for farmers who use production contracts. Both estimates are highly significant. Also, we strongly reject the hypothesis that $\gamma_1 = 1$ in both groups, which lends strong support for the model specifications in Eq. (5.13). Based on the estimated values of the relative risk aversion coefficients, one can conclude that those farmers who use production contracts are more risk averse than those farmers who use cash/marketing arrangements. The obtained results are consistent with the economic intuition that those farmers who are more risk averse self-select themselves into less risky arrangements.[7]

In production contracts, a significant amount of risk is transferred from a farmer to an integrator or a packer, because payment mechanisms typically insulate contract operators from market price volatilities. The companies that offer contracts are typically quite large and sometimes publicly owned and are therefore better positioned to bear risk than small farmers.

On the other hand, those farmers who use cash/marketing arrangements are exposed to substantially more risk than their contract counterparts. In fact, those farmers who sell their hogs on the spot market bear the entire enterprise risk that consists of price risk, production risk, and market access risk, whereas those using marketing contracts may be able to transfer market access risk and perhaps a portion of the price risk to the contractors.

5.3.4 Risk Aversion and Contract Choice

One way to look at the importance of risk aversion for contract choice is to perform a counterfactual experiment whereby production contracts would be eliminated as a contract choice for a group of farmers. Farmers who originally self-selected themselves into production contracts would suffer a utility loss as a result of being forced into a contract not reflective of their type. To quantify the effects of such a restriction on producers' utility, we run a counterfactual experiment as follows. First, with the estimated model primitives, we can use Eq. (5.16) to recover the unobserved heterogeneity in the disutility of production costs for each farmer in the data set in the following manner:

$$\hat{\varepsilon}_i^d = \hat{\gamma}_1^d \left(p_i^d q_i^d\right)^{\hat{\gamma}_1^d - 1} p_i^d - \hat{\alpha}_{1i}^d - \hat{\alpha}_2^d q_i^d \ . \tag{5.19}$$

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[7] This result is also consistent with the channel contract behavior literature. For example, Pennings and Wansink (2004) also found that risk attitudes varied widely among Dutch hog producers; 39% were risk averse, 4% risk neutral, and 57% were risk seeking. Pennings and Smidts (2000) found that the degree of risk aversion is important in explaining owner-managers' choice between relatively safe fixed-price contracts versus spot market transactions. However, as shown in Pennings and Smidts (2003), more structural organizational behavior, such as owners-managers' design of the production process, is not related to the degree of risk aversion but rather to the global shape of the utility function.

Next, we compute the payoff premium (mark-up) for each farmer as

$$m_i = \frac{p_i^d}{\overline{p}^d} \quad , \qquad (5.20)$$

where $\overline{p}^d$ is the average transaction payoff for farmers who use the marketing arrangement *d*. In the rest of this section, we use d = 1 to denote the joint cash (negotiated) and marketing contracts arrangement and d = 2 for production contracts. If the farmer uses cash/marketing arrangements, the payoff is the spot or marketing contract price he received for delivered live hogs. If the farmer uses production contracts, the payoff is the contract payment (service fee) per hog for the husbandry services rendered to the principal.[8]

At this point, we compute the market equilibrium by bringing the packers' derived demand for live hogs into the model. We assume that the inverse factor demands for the live hogs through different channels satisfy the following relationship:

$$\overline{p}^c = \alpha_0 + \alpha_1 Q^c + \alpha_2 Q^p + \alpha_3 \overline{P} + e^c$$

$$\overline{p}^p = \beta_0 + \beta_1 Q^c + \beta_2 Q^p + \beta_3 \overline{P} + e^p \quad , \qquad (5.21)$$

where $\overline{p}^c$ and $\overline{p}^p$ are the average prices packers pay for live hogs in cash/marketing and production contracts arrangements, respectively; Q^c and Q^p are quantities of hogs coming through the two channels; $\overline{P}$ is the average price of pork in the downstream market; and e^c and e^p are error terms. Notice that the average contract payment for farmers who use production contracts, $\overline{p}^2$, is different from the average price packers pay for hogs coming from the production contracts channel $\overline{p}^p$. This is because packers also need to pay for feeder pigs, feed, and other inputs they are responsible for supplying under the contract terms. We assume a fixed proportion between the two prices specified by $\overline{p}^2 = f\overline{p}^p$. To

[8] Notice also that the unobserved heterogeneity in the disutility of production costs $\hat{\varepsilon}_i^d$, recovered from Eq. (5.19), can be used to predict q_i^d for each value of p_i^d for all farmers in the data set. The supply response of an increase in price is obtained by using the relationship $q_i^d = q(p_i^d, \hat{\varepsilon}_i^d, \hat{\gamma}_1^d, \hat{\alpha}_{1i}^d, \hat{\alpha}_2^d)$ where $q(p_i^d, \hat{\varepsilon}_i^d, \hat{\gamma}_1^d, \hat{\alpha}_{1i}^d, \hat{\alpha}_2^d)$ is implicitly defined by Eq. (5.19). The corresponding supply elasticity for the cash/marketing channel is 3.02.

close the model, we further assume that the consumers' inverse demand for pork takes the form

$$\overline{P} = \gamma_0 + \gamma_1 Q^c + \gamma_2 Q^p + \gamma_3 \overline{B} + e^P \quad , \tag{5.22}$$

where $\overline{B}$ is the average price of beef, a substitute for pork. This specification captures the fact that hogs through different marketing arrangements may be of different qualities and hence affect pork prices differently. Appendix D describes in detail the data and the estimation procedure used to obtain the estimates of the above factor demand equations for live hogs and the final demand equations for pork.

Now, as an example, let's eliminate the use of production contracts in North Carolina and compute the new market equilibrium prices and quantities. Farmers in North Carolina who originally used production contracts must now use cash/marketing arrangements or shutdown. The new set of average prices $(\overline{p}_n^c, \overline{p}_n^p, \overline{P}_n)$ is found based on the following relationships:

$$\begin{aligned}
\overline{p}_n^c &= \hat{\alpha}_0 + \hat{\alpha}_1 \left[\sum_{i=1}^{N^c} \omega_i q_{i,n}^1 (p_{i,n}^1, \varepsilon_{i,n}^1) + \sum_{i=1}^{N^{switch}} \omega_i q_{i,n}^1 (p_{i,n}^1, \varepsilon_{i,n}^{switch}) \right] \\
&\quad + \hat{\alpha}_2 \sum_{i=1}^{N^p} \omega_i q_{i,n}^2 (p_{i,n}^2, \varepsilon_{i,n}^2) + \hat{\alpha}_3 \overline{P}_n + \hat{e}^{c,2004} \\
\overline{p}_n^p &= \hat{\beta}_0 + \hat{\beta}_1 \left[\sum_{i=1}^{N^c} \omega_i q_{i,n}^1 (p_{i,n}^1, \varepsilon_{i,n}^1) + \sum_{i=1}^{N^{switch}} \omega_i q_{i,n}^1 (p_{i,n}^1, \varepsilon_{i,n}^{switch}) \right] \\
&\quad + \overline{\beta}_2 \sum_{i=1}^{N^P} \omega_i q_{i,n}^2 \, (P_{i,n}^2, \varepsilon_{i,n}^2) + \hat{\beta}_3 \overline{P}_n + \hat{e}^{p,2004} \\
\overline{P}_n &= \hat{\gamma}_0 + \hat{\gamma}_1 \left[\sum_{i=1}^{N^c} \omega_i q_{i,n}^1 (p_{i,n}^1, \varepsilon_{i,n}^1) + \sum_{i=1}^{N^{switch}} \omega_i q_{i,n}^2 (p_{i,n}^2, \varepsilon_{i,n}^{switch}) \right] \\
&\quad + \hat{\gamma}_2 \sum_{i=1}^{N^p} \omega_i q_{i,n}^2 (p_{i,n}^2, \varepsilon_{i,n}^2) + \hat{\gamma}_3 \overline{B} + \hat{e}^{P,2004} \quad .
\end{aligned} \tag{5.23}$$

Here, N^c is the number of farmers who used the cash/marketing arrangement in the old scenario and continue using this channel in the new scenario, N^{switch} is the number of farmers who originally used production contracts in the state affected by the hypothetical restriction and now have to switch to the cash/marketing arrangement, N^p is the number of farmers in other states who originally used and will continue to use production contracts because they are not affected by the hypothetical restriction, ω_i is the individual farmer's expansion weight, $q_{i,n}(p_{i,n},\varepsilon_{i,n})$ is the predicted output for farmer i in the new scenario with new price $p_{i,n}$ and new unobserved heterogeneity $\varepsilon_{i,n}$.

The prices that individual farmers will receive in this new scenario are determined as

$$p_{i,n}^{1} = m_i \times \overline{p}_n^{c}; \quad p_{i,n}^{2} = m_i \times \hat{f} \times \overline{p}_n^{p} \tag{5.24}$$

and the unobserved heterogeneity is determined as

$$\varepsilon_{i,n}^{1} = \hat{\varepsilon}_i^{1}; \quad \varepsilon_{i,n}^{2} = \hat{\varepsilon}_i^{2}; \quad \varepsilon_{i,n}^{switch} = \frac{(\hat{\sigma}_{\varepsilon}^{2})^{1}}{(\hat{\sigma}_{\varepsilon}^{2})^{2}}\hat{\varepsilon}_i^{2} \;, \tag{5.25}$$

with $f = \dfrac{\overline{p}^{2}}{\overline{p}^{p}}$. Eq. (5.25) says that for a farmer who is not

affected by the restriction, the unobserved heterogeneity will remain the same. However, for a farmer who originally used production contracts in the state with the new restriction, the new unobserved heterogeneity will be equal to his recovered unobserved heterogeneity in production contracts scaled by the variances of the unobserved heterogeneity in the two channels. All above assumptions are reasonable. They imply that a high ability contract grower who received better than average contract payments will transfer his superior skills to another type of marketing arrangement and will remain a high ability producer whose price will exceed the average market price by the same margin. The same argument applies to the unobserved heterogeneity in the disutility of production costs. Finally, we calculate $q_{i,n}$ for all farmers using the first order condition Eq. (5.14) and numerically search for the new set of average prices that clear the market. With the new set of market equilibrium prices, we can predict each farmer's output level and then compute the change in his utility.[9]

The effects associated with this hypothetical restriction can be measured by the *compensating variation*, defined as the amount of money that, when taken away from a farmer after the hypothetical restriction, leaves the farmer just as well off as before. In the case of a gain, it is the maximum amount that the farmer would be willing to pay for the restriction. In the case of a loss, it is the negative of the minimum amount that the farmer would require as compensation for the imposed restriction. The *CV* measure is obtained as the solution to the following relationship:

$$U(R(q_o),C(q_o),\gamma) = U(R(q_n) - CV,C(q_n),\gamma)\ , \qquad (5.26)$$

where q_o is a farmer's production level in the old equilibrium and q_n is a farmer's production level in the new equilibrium under a restriction.[10] A positive *CV* means the farmer benefits from the restriction; a negative *CV* means the farmer loses under the restriction.

The relevant results can be summarized as follows. As a result of a hypothetical ban of production contracts in North Carolina, the average national price in the cash/marketing arrangement will increase from $119.75 to $125.61 per hog. On the other hand, the average contract payment would decrease by about 2%. Different farmers respond to the new market conditions differently. Cash farmers, both those in North Carolina and outside, produce more hogs because the cash price would go up. On the other hand, production contracts farmers in North Carolina, who are the target of this hypothetical restriction, are forced to switch to cash/marketing arrangements, which are inherently more risky than production contracts. Because they

[9] Notice that this model could be used to compute the overall farm-level effects associated with different types of regulatory proposals, provided that the first stage of the model can be estimated. The fact that we do not estimate the first stage of the model forces farmers in unaffected states to remain in their originally chosen marketing arrangements. However, in reality, farmers could switch from cash marketing to production contracts or *vice versa* if the change in relative prices of hogs in two marketing channels is sufficiently large to justify the switch.

[10] For those farmers who switch from the production channel to the cash/marketing channel because of the hypothetical restriction, the revenue function and the cost function also change along with the production level.

are risk averse, they react by reducing their risk exposure and thus reducing their supply by almost 99%.[11] As the result, a typical North Carolina contract farmer's utility loss would amount, on average, to $80,892 per year. This is because highly risk-averse farmers are forced to switch to riskier cash/marketing arrangements. To reduce their risk exposure, they reduce their volume of output and consequently earn much less than before.

5.4 SUMMARY

In this section, we analyzed the transfer of risk from risk-averse farmers to risk-neutral (or less risk-averse) firms (integrators and packers), and the importance of producers' risk aversion for the choice of marketing arrangements in the hog industry. We were able to show the following:

- Different types of marketing arrangements exhibit different price volatilities as measured by the variance of price; thus, they may subject the producers selling their hogs through these channels to different levels of risk. The ordering of marketing arrangements by the risk they carry is quite intuitive:
  - spot/cash market sales;
  - marketing contracts whose pricing formula is based on different spot markets;
  - marketing arrangements whose pricing formula is based on some futures or options price; and
  - other purchase arrangements containing ledgers, windows, and other pricing mechanisms, which may serve to moderate price volatility.

  Most of those variances are statistically significantly different from each other.

- Related to risk shifting associated with production contracts, we found that in a typical contract settlement formula, production contracts eliminate about 94% of the total income variability if one uses income volatility of an independent market hog producer as the benchmark. This is because production contracts insulate growers from both input price and output price

[11] The contract production also drops outside North Carolina by about 4% as a result of slightly lower contract grower payments, and the total number of hogs produced in the United States drops by about 7%.

risks, so the only component of risk remaining is production risk, which is quite small.

- Finally, we showed that farmers who use production contracts are more risk averse than farmers who use cash/marketing arrangements. The obtained results are consistent with the economic intuition that those farmers who are more risk averse self-select themselves into less risky activities. The difference in risk exposure between contract producers and independent farmers is substantial as production contracts eliminate all but 6% of total income volatility. Therefore, it is not surprising that the losses utility associated with forcing producers to market their hogs through channels different from their risk-aversion-preferred marketing arrangement choice are substantial.

6 Measurement of the Economic Effects of Restricting Alternative Marketing Arrangements

This section reports on the effects of restricting AMAs on the markets for hogs and pork. The analysis is comprehensive in the sense that all economic agents are accounted for in the analysis, from the farm gate through retail level. We describe the modeling approach followed by the results of three simulation scenarios below.

6.1 MODELING APPROACH FOR CONDUCTING SIMULATIONS OF RESTRICTIONS ON AMAS IN THE PORK INDUSTRY

The model used to conduct simulations consists of 18 equations—six demand equations for primal pork cuts; six price equations for the primal pork cuts; three input demand equations for negotiated, contract, and packer-owned hogs; and three equations describing supply response of producers in each of the three hog categories. Although the demand equations are strictly at the wholesale level, they are specified as derived demand equations from retail demand for pork and therefore account for any effects of changes in the composition of AMAs on marketing channels downstream from the wholesale level. The main reason for using a disaggregated model is to account for the fact that the three sources of hogs are substitutes in packing and processing of pork, and that these marketing instruments can have different effects on the productivities and cost efficiencies of slaughtering and processing hogs. Moreover, the composition of primal pork cuts produced can be affected by the composition of hogs from the three different sources. Therefore, by disaggregating demand and prices of these cuts, we account for any changes in quality that might occur as a result of altering the composition of the portfolio of hogs slaughtered.

The econometric model used in the analysis is described in detail in Appendix B, and only an overview of its structure is provided here. Particular attention was given to developing the packer behavior component of the model. Specifically, the model developed is built on a general theory of a firm that is engaged in acquiring different inputs (the three types of market hogs), producing, and selling the six different primal pork cuts. Firms are assumed to choose inputs and outputs to maximize profit. Firms are also allowed to be imperfectly competitive in the markets for hogs and markets for the pork cuts. Therefore, care is taken to allow for the influence of packer behavior on pricing of both inputs and outputs. On the input side, market prices adjust to changes in quantities of the three types of hogs and anticipated demand for pork; on the output side, market prices adjust to changes in quantities of the six different pork cuts, given the supply of slaughtered hogs available for processing. Dynamic seemingly unrelated regressions method (DSUR) is used to estimate the nine packer relationships. The reason for selecting this method is to simultaneously account for unit roots in the explanatory variables, dynamics in the weekly behavioral equations, and endogeneity arising from both nonstrict exogeneity of the regressors and possible joint determination of prices and quantities in the market. The DSUR method deals with these issues while at the same time providing for correction of the model so that classical hypothesis testing can be used for hypothesis testing.

Wholesale demand models for the pork cuts were estimated using the absolute price version of the Rotterdam Model. This model produced very reasonable estimates, and the results indicated that the theoretical restrictions held. Parameter estimates of the model were integrated with external estimates of demand for pork as a group to develop unconditional uncompensated demand parameters to use in the analysis.

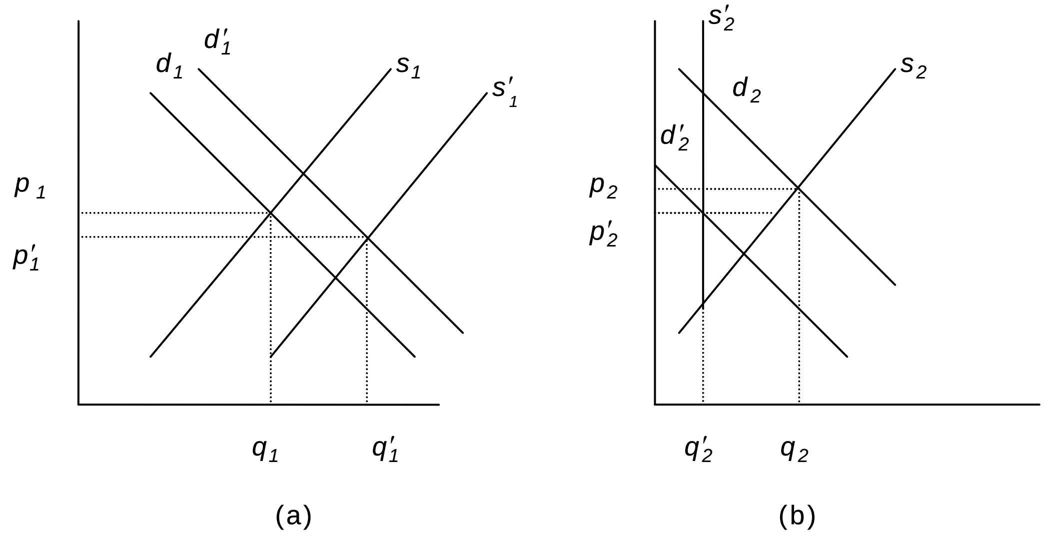
The model was closed with three input supply specifications. The parameter estimates for supply response were developed for two lengths of run—the short run and long run. The short-run estimates assume approximately 1 year for adjustment to any imposed restrictions. The long-run estimates assume a 10-year adjustment to a permanent regulatory change. The supply elasticities for these different lengths of run were obtained from two other detailed studies on producer response in the short run and the long run, both described in Appendix B.

Once the parameter estimates of the 18 equation model were obtained, they were used together with assumed restrictions to simulate changes in prices and quantities of the six pork primals and the three hog types. The quantity and price changes computed are equilibrium changes, meaning that they account for effects on all economic agents—producers, processors, and consumers. Moreover, the markets interact in such a way that new equilibrium levels are reached in response to the regulatory change that occurs.

To understand what is entailed in the analysis, consider a simple scenario where the supply of hogs through AMAs as a group is decreased by a given amount because of restrictions on AMA use. As shown in Figure 6-1, a decrease in supply of hogs from AMAs due to a restriction (panel b) causes the supply curve s_2 to fall and become kinked as shown by s_2'. Because of reduced availability of supplies from that source, packers bid up the price of hogs on the spot market, causing demand to increase from d_1 to d_1' (panel a). In response to the higher price on the spot market, producers will shift out of the AMA supplies market and increase supply of hogs to the spot market causing supply to increase in that market. At the same time, an increased availability of hogs from the spot market causes packers to reduce demand for hogs from AMA supplies causing demand for hogs from AMA markets to decrease.

It is important to recognize that the supply shifts in both markets come about because of the restriction that total supply must equal the sum of supplies to both markets. Even if the supplies in both markets are independent of one another (i.e., do not depend directly on price on the other outlet), it is the

Figure 6-1. Effect on Negotiated Sales and AMA Supplies from a Restriction Reducing Availability of Hogs in the AMA Supplies Market



case that, if supply in one market decreases at a given price (which is the case for AMA supplies), then supply in the other market must increase by that same amount at its original price. *This is because the supply reduction is not voluntary but would come about through a required restriction. Producers are willing to supply the original quantity at the going price in the AMA supplies market so they must be willing to supply the same quantity at that price (net of any transfer costs) in the negotiated market.* Additional adjustments along the supply curves occur as the demand curves shift in response to changes in quantities marketed.

The above description assumes (a) that the different AMAs are substitutes in demand, and (b) that the increase in supply in the spot market exceeds the increase in demand resulting from restricting sales in the AMA supplies market. As shown below in the simulations, both of these assumptions are validated, although for other applications the assumptions may not be valid.

The economic effects of restricting sales for AMA supplies consist of (a) effects on producers selling in the spot market, (b) producers selling in the AMA supplies markets, (c) effects on consumers buying pork products, and (d) effects on packers' net revenues. Comparative static formulas to compute equilibrium changes in the quantities and prices of the six pork cuts and the three hog AMAs were derived from the 18-equation econometric model of the pork/hog industry. Formulas for computing changes in economic surplus on producers, consumers, and packers were then developed. Appendix B provides details on these computations.

Table 6-1 shows the reduced-form, inverse industry derived demand flexibilities for the alternative sources of hog procurement. The total effects show strong substitution among the different AMAs. This pattern of substitution is consistent with the commonly observed phenomena that increased quantities or shares of contract and packer-owned hogs have a depressing effect on the spot price.[1]

Table 6-1. Reduced-Form, Inverse Industry Derived Demand Flexibilities for Hogs from Alternative Market Sources

Market Source	Negotiated	Contract	Packer Owned
Negotiated	–0.26698155	–0.875654	–0.281093
Contract	–0.14678056	–0.536174	–0.166386
Packer Owned	–0.17248395	–0.620852	–0.176251

6.2 RESULTS OF SIMULATIONS OF RESTRICTIONS ON AMAS IN THE PORK INDUSTRY

Three types of simulations were performed: (a) 25% reduction in both contract and packer-owned hogs, (b) increase of the spot/cash market share to 25%, and (c) complete banning of packer-owned hogs. The simulations were performed over both the short run and the long run (10-year adjustment period). The results for changes in prices and quantities are presented as percentage changes from the baseline prices and quantities. The results in the tables for economic surplus effects are presented in terms of percentages of total revenue of hog production or pork production, depending on the economic surplus measure.

[1] See Section 2 for analysis of this issue.

Table 6-2 shows the short-run effects on prices and quantities from Scenario (a)—25% reduction in both contract and packer owned supplies. Over the sample period, August 10, 2001, through September 30, 2005, contract supplies (an aggregate of marketing and production contracts) accounted for approximately 67.3% of the value of all hog marketings, and packer owned supplies accounted for about 19.8%, leaving about 12.9% sold on the spot market. Contract supplies over this time period ranged from about 62.6% to 72.0%, packer owned supplies ranged from approximately 15.4% to 22.5%, and negotiated supplies ranged from approximately 8.9% to 18.5%. At the sample means, 25% reductions in contract and packer owned supplies mean that the share of contract supplies would decline to 50.5% and packer owned supplies would decline to 14.5%, holding total supply fixed. Of course, total supply would be expected to decline somewhat because prices would also be expected to decline. Therefore, the final shares of contract and packer owned supplies would be somewhat different than 50.5% and 14.5%, respectively. At any rate, this simulation would be expected to have rather large effects on prices and quantities, as Table 6-2 shows.

Table 6-2. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (a) (Short Run)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	5.071995	Y1	–6.254235
Butt	P2	6.047142	Y2	–4.321752
Ham	P3	0.129534	Y3	7.824395
Rib	P4	0.811994	Y4	4.340150
Belly	P5	4.280122	Y5	–0.690170
Picnic	P6	4.038218	Y6	2.858603
Negotiated	W1	–8.993384	X1	142.073600
Contract	W2	–3.287139	X2	–25
Packer owned	W3	–4.566955	X3	–25

Negotiated prices (spot market prices) would be expected to decline almost 9%, while unit returns from contracting and packer-owned hogs would be expected to decline 3.3% and 4.6%, respectively. The fact that hog prices would be expected to decline reflects the fact that the net effect of the restriction would reduce efficiencies in processing hogs more than it would offset the decline in market power from reducing AMA supplies. We would also expect to see a rather large increase in hogs supplied on the spot market—predicted to increase some 142% from the original base. As indicated above, the increase comes from supplies diverted from contract and packer owned supplies. The rather large reductions in quantities of contract and packer-owned hogs (given the initial market shares) to meet the 25% reduction criterion mean that supply in the spot market must increase by a rather large amount because of the small initial quantity supplied to the spot market. Average pork production over the sample period was 19,792 million pounds on a per annum basis. Total pounds of hogs (in carcass weight) sold on the spot market was about 2,553 million pounds on a per annum basis. An increase of 142% translates into an increase in spot market sales to approximately 6,178 million pounds. AMA supplies (contract plus packer-owned hogs) were approximately 17,238 million pounds on average over the sample period. With a 25% reduction in supplies, AMA supplies would decrease to approximately 12,929 million pounds. Therefore, the new total quantity of pork produced would be 16,554 million pounds, approximately a 3.6% reduction in total supply of pork. The new percentages of negotiated supplies and AMA supplies would be 32.3% and 67.7%, respectively.

The effect on pork production and pork prices would not be expected to be uniform across the different pork primals. Loins, butts, bellies, and picnics would be expected to experience the largest price increases. Quantities produced and sold would decline significantly for loins and butts, but only slightly for bellies. Quantities sold of the other primal cuts would actually increase, with the largest increase occurring for hams and ribs.

A quality index has been computed to determine how much quality of pork would be affected by the restriction. The quality index is computed as the share-weighted sum of quantities of primal pork cuts, each weighted by its sample average price. The index therefore measures the effects of changes in the composition of cuts within the composite good. Shifts away from cuts with low per-unit value to cuts with high per-unit value would indicate an increase in quality, while shifts away from high-value to low-value cuts would indicate a decrease in quality.[2] The change in quality, as a percentage from its original level, would decrease by 0.9% from a regulated decrease in quantities of contract and packer-owned hogs.

For the quantity of hogs as an input into pork processing, we can also compute a change in quality in the same way we did for the change in quality of pork, by multiplying the share-weighted sum of quantities of hogs from negotiated, contract, and packer owned sources by their sample average prices. Following this procedure for the quantity of hogs slaughtered we find that quality would be expected to decrease by 0.5% from its original level.

Table 6-3 presents economic surplus effects on producers, processors, and consumers from Scenario (a). These changes are shown as percentages of total hog value for producers' surplus, and as percentages of total pork value for processors' net revenue and consumers' surplus. Both producers and consumers lose from this scenario, but processors gain from it. On the face of it, it seems counter-intuitive that processors would gain. However, it is important to understand that packers are market middlemen and can pass on some, all, or even more of the cost increase to consumers and producers. Indeed, in this scenario we find that the average pork price would increase 3.7% and the average hog price would decrease 4.3%. The price spread between farm and wholesale would increase 7.4%.[3] In general, regardless of whether the industry is composed of competitive or imperfectly competitive firms, we would expect profits to increase when input prices fall. For firms exercising market power for the raw material, profits could rise even more (Chen and Lent, 1992). Coupled with an increase in output price, if the effect from a fall in input price is large enough, it could offset the increase in marketing costs arising from a decrease in AMA supplies to cause profits to rise. This is apparently the case when both contract and packer owned supplies are reduced and diverted to the spot market. Indeed, total input expense for hogs for the industry declines by 8.6%,

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[2] The quality index is due to Theil (1952–53). Nelson (1991) says that such a measure captures quality changes associated with composite goods like pork.

[3] The percentage change in the price spread is calculated as the percentage change in pork price minus the farm–wholesale farm ratio times the percentage change in hog price, 3.7–(0.85) x (–4.3).

Table 6-3. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Scenario (a) (Short Run)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–3.91821
Changes in processor's net revenue (% of total revenue of pork)	3.220613
Changes in producer's surplus (% of total revenue of hog production)	–18.49855

or almost $1 billion. Total revenue from pork sales in the short run would increase about $0.3 billion. Thus, the increase in value added from hog slaughtering is estimated to be enough to offset the increase in costs from reallocating AMA supplies.

On the production side, it is clear that all producers would be worse off because of a uniform fall in prices received on the spot market and for hogs grown under contract.[4] Total revenue from hog production from August 2001 through September 2005 was about $12 billion. Thus, in the short run, producers would be expected to lose approximately $2.2 billion. The average number of hogs slaughtered was about 98 million, meaning producers would be expected to lose about $22 per hog.

Average total revenue of pork sold by packers was $13 billion over the sample period. The loss to consumers in the short run would be about $507 million per year. The gain to processors would be approximately $419 million per year. The total loss in surplus from the restriction would be about $2.3 billion, with a substantial portion of the burden falling on producers. As indicated at the outset, the scenario of reducing all AMA supplies by 25% is substantial for the hog industry because of the high initial proportion of hogs sold under contract and produced by companies.

The long-run effects of Scenario (a) on prices and quantities are shown in Table 6-4, while the long-run effects on consumers, processors, and producers are shown in Table 6-5.

[4] Changes in producers' surplus for packer owned hogs are included in the effects on processors' net revenue.

Table 6-4. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (a) (Long Run: 10-Year Adjustment Period)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	7.671774	Y1	–9.459999
Butt	P2	9.146756	Y2	–6.536973
Ham	P3	0.195929	Y3	11.83498
Rib	P4	1.228201	Y4	6.564803
Belly	P5	6.474005	Y5	–1.043934
Picnic	P6	6.108108	Y6	4.323851
Negotiated	W1	–5.26687	X1	128.152
Contract	W2	–1.24245	X2	–25
Packer owned	W3	–2.16014	X3	–25

Table 6-5. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Scenario (a) (Long Run: 10-Year Adjustment Period)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–6.084669
Changes in processor's net revenue (% of total revenue of pork)	1.128958
Changes in producer's surplus (% of total revenue of hog production)	–10.35059

These effects, which were computed assuming a 10-year period for adjustment, indicate as one might expect that producers bear a smaller portion of the cost increase, consumers bear a larger portion of the cost increase, and that the effect on processors is now almost neutral. The dollar loss to consumers would be expected to be $791 million, an increase of 56% from the short run. Processors would still gain $147 million after 10 years, although as more time passed they would eventually neither gain nor lose. Producers would lose $1.24 billion, or an average of about $12 per hog marketed.

As a check on the calculations performed for Scenario (a), we developed an alternative model that is more transparent on the workings of the markets. The model consists of monthly supply/demand relationships for hogs and pork. An aggregate farm–wholesale price relationship was estimated as a function of the aggregate price of hogs, production of pork, and index of marketing costs (consisting of labor and energy costs) and the proportion of hogs sold as AMA supplies. A wholesale demand function for pork was also estimated, and the supply elasticities of hogs used for the 18-equation disaggregated model were also used in the analysis to compute short-run and long-run effects. It is difficult to compute economic surplus effects with such an aggregate model because of the diversion of supplies from contracts and packer owned sources to the spot market. However, estimates of changes in prices and quantities can be computed to see what the relative magnitudes are and to compare them with the results we have in Tables 6-2 and 6-4. Appendix B develops these relationships in detail. The reason this model seems appropriate for Scenario (a) is that both contract and packer owned supplies are each changed by the same proportion so the assumptions of the simulation fit with the aggregate model pretty well.

The elasticity of demand for pork at the wholesale level was estimated to be –0.38. The supply elasticity of hogs in the aggregate for the short run was estimated to be 0.79. The parameters of the farm–wholesale price spread include the elasticity of price transmission between the farm and the wholesale level, estimated to be 0.86 and the elasticity of wholesale price with respect to a 1% change in AMA supplies, estimated to be –1.5.[5] Assuming the proportional change in quantity of hogs slaughtered equals the proportional change in quantity of pork produced, we estimate that a 1% decrease in AMA supplies decreases the spot price of hogs by about 0.5%. For the scenario of a 25% reduction in AMA supplies, this would translate into about a 12.5% reduction in the spot price. Note that this price decrease prediction compares with a reduction of about 9% predicted from the disaggregated model (Table 6-2). The main reason for the difference is that the disaggregated model yields a larger elasticity of demand for hogs of about –0.9 by accounting for substitution among different sources of hog procurement. Certainly, this prediction with the monthly

[5] There is also an elasticity of wholesale price with respect to quantity (estimated to be 0.04), but it was ignored in the calculations because it has negligible effects on the results.

model indicates that the predictions from the disaggregated model are not overstated.[6]

Table 6-6 shows the short-run effects on prices and quantities from Scenario (b)—decrease in shares of contract and packer owned supplies to achieve a 25% market share for negotiated sales. To achieve the goal of a 25% market share for spot sales, both contract and packer owned sales would each have to decline by about 14%. This would lead to an increase in hog sales on the spot market by about 71.4%, from approximately 2,553 million pounds to 4,375 million pounds on a per annum basis. AMA supplies would decline from 17,238 million pounds to approximately 14,825 million pounds.

Table 6-6. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (b) (Short Run)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	2.824217	Y1	–3.482518
Butt	P2	3.367203	Y2	–2.406462
Ham	P3	0.072128	Y3	4.356823
Rib	P4	0.452139	Y4	2.416707
Belly	P5	2.383281	Y5	–0.384305
Picnic	P6	2.248583	Y6	1.591743
Negotiated	W1	–5.007746	X1	79.1102
Contract	W2	–1.830363	X2	–13.92064
Packer owned	W3	–2.542997	X3	–13.92064

Spot market prices would be expected to decline about 5% under this scenario, while unit returns for contracting and packer ownership would be expected to decline by 1.8% and 2.5%, respectively. As before, the fact that hog prices would be expected to decline reflects the fact that the net effect of the restriction would be to reduce efficiencies in processing hogs more than it would offset the decline in market power from reducing AMA supplies.

We see very similar effects on pork production and pork prices as Scenario (a). As before, loins, butts, bellies, and picnics

[6] See Appendix B, Attachment 3 for details on the computations with the monthly model.

would be expected to experience the largest price increases. Quantities produced and sold would decline significantly for loins and butts, but only slightly for bellies as before. Also, quantities of hams and ribs sold would increase.

Quality indexes for both pork and hogs fall as before, but by smaller amounts. Quality of pork drops only 0.5% and quality of hogs as an input drops only 0.3%.

Table 6-7 presents economic surplus effects on producers, processors, and consumers from Scenario (b). These effects have the same signs as those indicated for Scenario (a), showing both producers and consumers losing and processors gaining (slightly) in the short run. As before, we find that the average pork price would rise (about 2% on average) and the average hog price would decrease (about 2.4% on average). The price spread between the farm and the wholesale level would increase about 4%. As before, this increase in the price spread is apparently enough to offset (slightly) the increase in costs entailed from reallocating hogs from AMA supplies to the spot market.

Table 6-7. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Scenario (b) (Short Run)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–2.131444
Changes in processor's net revenue (% of total revenue of pork)	1.711562
Changes in producer's surplus (% of total revenue of hog production)	–8.569028

Producers are worse off by about $1.03 billion or $10.50 per hog. Consumers would lose about $277 million per year, and processors would gain about $222 million per year.

The long-run effects of Scenario (b) on prices and quantities are shown in Table 6-8, while the long-run effects on consumers, processors, and producers are shown in Table 6-9. These effects, which are computed assuming a 10-year period for adjustment, indicate as in Scenario (a) that producers bear a smaller portion of the cost increase, consumers bear a larger portion of the cost increase, and the effect on processors is now

Table 6-8. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (b) (Long Run: 10-Year Adjustment Period)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	4.27184	Y1	–5.267569
Butt	P2	5.093148	Y2	–3.639954
Ham	P3	0.109099	Y3	6.590022
Rib	P4	0.683894	Y4	3.65545
Belly	P5	3.604892	Y5	–0.581289
Picnic	P6	3.401151	Y6	2.407631
Negotiated	W1	–2.932727	X1	71.35833
Contract	W2	–0.691827	X2	–13.92064
Packer owned	W3	–1.20282	X3	–13.92064

Table 6-9. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Scenario (b) (10-Year Adjustment Period)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–3.272983
Changes in processor's net revenue (% of total revenue of pork)	0.59449
Changes in producer's surplus (% of total revenue of hog production)	–5.347453

almost neutral. The dollar loss to consumers is expected to be $425 million, almost a doubling from the short run. Processors would gain $77 million after 10 years, although as more time passed they would eventually neither gain nor lose. Producers would lose $642 million per year, or an average of about $6.55 per hog marketed.

Table 6-10 shows the short-run effects on prices and quantities from Scenario (c)—the effects of a complete ban on packer-owned hog production. The effect of a ban on packer owned sales would be for sales in the spot market to increase from 2,553 million pounds carcass weight to 5,967 million pounds on a per annum basis. AMA supplies would decline from 17,238 million pounds to approximately 13,172 million pounds.

Table 6-10. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (c) (Short Run)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	4.844295	Y1	–5.902172
Butt	P2	5.770456	Y2	–4.08273
Ham	P3	0.137115	Y3	7.453754
Rib	P4	0.781763	Y4	4.149452
Belly	P5	4.090397	Y5	–0.650994
Picnic	P6	3.877224	Y6	2.71754
Negotiated	W1	–6.64345	X1	133.8008
Contract	W2	–2.40705	X2	–1.107242
Packer owned	W3	–4.76595	X3	–100

Spot market prices would be expected to decline about 6.6% under this scenario, while unit returns for contracting would be expected to decline by 2.4%. As in the other simulations, the fact that hog prices would be expected to decline reflects the fact that the net effect of the restriction would be to reduce efficiencies in processing hogs more than it would offset the decline in market power from reducing AMA supplies.

The expected effects on pork production and pork prices are that loins, butts, bellies, and picnics would have the largest price increases. Quantities produced and sold would decline significantly for loins and butts, but only slightly for bellies. Also, quantities of hams and ribs sold would increase.

Quality indexes for both pork and hogs fall as in the other simulations. Quality of pork drops 0.8% and the quality of hogs as an input drops 1.2%.

Table 6-11 presents economic surplus effects on producers, processors, and consumers from Scenario (c). These effects have the same signs as those indicated for Scenario (a), showing both producers and consumers losing and processors gaining (slightly) in the short run. As before, we find that the average pork price would rise (on average about 3.5%) and the average hog price would decrease (on average about 3.4%).

Table 6-11. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Scenario (c) (Short Run)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–3.73782
Changes in processor's net revenue (% of total revenue of pork)	0.704409
Changes in producer's surplus (% of total revenue of hog production)	–11.77878

The price spread between the farm and the wholesale levels would increase about 6.5%. As in the other simulations, this increase in the price spread is apparently enough to offset (slightly) the increase in costs entailed from reallocating hogs from AMA supplies to the spot market.

Producers are worse off by about $1.4 billion or $14.42 per hog. Consumers would lose about $485 million per year, and processors would gain about $91 million per year.

The long-run effects of Scenario (c) on prices and quantities are shown in Table 6-12, while the long-run effects on consumers, processors, and producers are shown in Table 6-13. These effects, which are computed assuming a 10-year period for adjustment, indicate as before that producers bear a smaller portion of the cost increase, consumers bear a larger portion of the cost increase, and the effect on processors is now negative. The dollar loss to consumers would be expected to be $736 million, an increase of over 50% from the short run. Processors would lose $108 million per year after 10 years. Producers would lose $739 million per year, or an average of about $7.54 per hog marketed.

6.3 SUMMARY

Three different simulations were performed to evaluate the effects of restricting AMA supplies on hog producers, pork producers, and pork packers. In all three simulations, hog producers lose because of the offsetting effects of hogs diverted from AMA supplies to the spot market. In addition, consumers lose as wholesale and retail pork prices rise. In the short run, packers gain, but in the long run they neither gain nor lose.

Table 6-12. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (c) (Long Run: 10-Year Adjustment Period)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	7.16477	Y1	–8.729382
Butt	P2	8.534572	Y2	–6.038406
Ham	P3	0.202795	Y3	11.02419
Rib	P4	1.156237	Y4	6.137088
Belly	P5	6.049745	Y5	–0.962828
Picnic	P6	5.73446	Y6	4.019274
Negotiated	W1	–3.696744	X1	125.0294
Contract	W2	–0.749186	X2	–1.798047
Packer owned	W3	–2.824136	X3	–100

Table 6-13. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Scenario (c) (Long Run: 10-Year Adjustment Period)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–5.660309
Changes in processor's net revenue (% of total revenue of pork)	–0.829551
Changes in producer's surplus (% of total revenue of hog production)	–6.155498

The reason that producers and consumers lose in all three simulation scenarios is because of efficiency losses from reducing the proportion of hogs sold through contracts and/or packer owned channels. Although a reduction in AMA supplies leads to an improvement for hog producers through a reduction in the degree of market power, the loss in cost efficiencies offsets the gains from reduced market power. In all instances, the price spread between farm and wholesale prices would be expected to increase because of the net increase in the costs of processing. Moreover, wholesale, and hence retail, prices would increase, causing pork to become more expensive for consumers.

7 Implications of Alternative Marketing Arrangements

In this section, we describe the implications of AMAs based on the outcome of the combined set of research activities conducted for the study. First, we describe qualitative results resulting from the interviews with hog producers and pork packers regarding the implications of restricting use of marketing arrangements. Then, we assess the economic implications of and incentives for changes in the use of AMAs in the pork industry in the future.

7.1 EXPECTED EFFECTS OF CHANGES IN MARKETING ARRANGEMENTS BASED ON THE INDUSTRY INTERVIEWS

> Prior to conducting the quantitative analyses for this study, we interviewed hog producers and pork packers to obtain qualitative information about the short- and long-term effects of a ban on packer ownership of livestock.

We interviewed pork producers and packers regarding their perception of the short-run and long-term impacts of a ban on packer ownership of hogs. They were asked to identify what adjustments their firm would make to such a restriction.

Three of the eight producers interviewed indicated that there would be no short-term effects on their business if packer ownership was banned. Two others indicated that they currently benefit from packer ownership of hogs through higher prices. They believe that there is competition for hogs between packers that own hogs and those that do not. Other producers thought that a ban on packer ownership of hogs would also restrict pork producers from forming a cooperative to own a packing plant. Some producers saw a benefit to packer ownership because packers could run their plant closer to capacity and because they owned hogs, they did not have an incentive to drive hog prices down.

Although they did not say how they would adjust their businesses, two producers did express concern about packer ownership. One concern was its impact on price discovery, but they felt that MPR had helped with this issue. The second concern was a general concern about the structure of the industry, the loss of medium-sized farms, and a trend toward more vertical integration. Still others believed that retailers had more market power and they were concerned about that issue.

Most of the pork producers interviewed believed that there would be no long-term impact on their firm because of a ban on packer ownership. A minority of those interviewed reported having only one buyer in the immediate area. If packers could not own hogs, they were concerned about competition for the hogs they have to sell if there is a regional monopoly.

Packers identified a variety of immediate adjustments to a ban on packer ownership depending on their current involvement in hog production. Packers that do not use contracts or own hogs said it would have no negative effect on their operations. They believed that they may benefit from having more hogs available on the open market and that the price may be less volatile with more open market hogs. Other packers reported that they would renegotiate marketing contracts with producers and convert contract growers to hog owners with long-term marketing contracts. There was a concern that some producers would not have the financial strength to own the facilities and the hogs and pay for feed and other production costs. Thus, some other party would have to own the hogs in the facilities if the packer cannot. Still other packers that currently own both hogs and packing plants said that they would have to choose which business to sell and which one to keep. Depending on who bought the packing company, or the hogs, it is possible that such a forced sale would lead to greater concentration in that sector of the industry.

As with the short-run implications, packers' perceptions of the long-term impact of a ban on packer ownership of hogs were mixed. Some thought that there would be little impact because there are successful packers that do not own hogs. Others were concerned that it would be more difficult to implement quality programs that have improved consumer demand and made pork more competitive with other meats. Two packers indicated that their greatest concern was the increased risk they face by not having a known supply of hogs for their plants. They also identified a negative impact on company returns from selling a profitable production enterprise. More importantly, they were concerned about a loss of asset value due to the ban. For some locations, the plant has much less value without a known supply of hogs; likewise, the hog facilities may have less value without a known market for the hogs.

Producers and packers were asked about the impact on costs and quality resulting from a ban on packer ownership. Producers did not have a response to either question. Although some packers said that there would be no cost impact from a ban on packer ownership, others identified increased procurement as the important cost. The cost would come from an increased procurement network of buyers and/or buying stations. These costs were estimated to be in the range of $0.20 to $0.53 per head.

The producer and packer interviews identified costs and lost revenue from a ban on packer ownership.

However, the packers that responded to the question about the effect on pork quality from restricting packer ownership felt strongly that pork quality would be negatively affected. They reported that it was very difficult to meet consumer quality expectations with spot market hogs. Specifically, they believed that quality programs like USDA Process Verified could not be met through the open market. As a result, value built in these programs would be lost. Although they recognize the value of the spot market, they believed that marketing agreements and carcass merit programs were necessary to improve pork quality.

The producer and packer interviews identified costs and lost revenue from a ban on packer ownership. Although producers did not quantify the cost, they were concerned in the short run about competition for hogs and plant efficiency that can affect their net prices. Other producers were concerned about packer ownership and its impact on industry structure and price discovery. Producers that are contract growers for a packer would also have to find another party to own the hogs or take on the financing and risk of owning the hogs in their buildings.

Producers did not believe that there would be significant long-run implications of a packer ownership ban.

Packers' responses differed by their current ownership of hogs. Some believed that they would benefit from the ban because it would make more hogs available on the open market. Those that own hogs were concerned about asset values of a forced sale or even which asset to sell—hogs or the plants. They also identified the added cost of procurement, and about half thought that pork quality would be damaged.

The model results in Section 6 estimated a significant cost to the industry from restricting packer ownership of hogs. The interview results do not appear to suggest as large an impact. Most of the producers and half of the packers did not expect there to be a major long-term impact to banning packer ownership. Producers and packers that are heavily invested in systems depending on packer ownership of hogs will have significant changes to their operations. However, they do not represent the entire industry. They and other participants expect they would be able to find ways to work through ownership restrictions over time.

7.2 IMPLICATIONS OF AND INCENTIVES FOR CHANGES IN USE OF ALTERNATIVE MARKETING ARRANGEMENTS OVER TIME

> Based on the evidence from this study, we expect the use of AMAs in the hog and pork industry to remain at levels similar to their current levels.

Based on our assessment of the pork industry from the industry interviews, industry surveys, and analyses of the transactions data as well as other public domain data sources, we expect the use of AMAs in the pork industry to remain at levels similar to their current use. Therefore, we predict that it is extremely unlikely that the industrialization of the hog industry will mimic the industrialization of the poultry industry (in particular, the broiler industry in which virtually 100% of production takes place on either packer-owned farms or via production contracts with independent growers). Instead, the combination of spot/cash markets, marketing contracts, and packer ownership is likely to prevail in the future, and substantial regional differences between the East (with predominant reliance on production contracts) and the Midwest (spot markets and marketing contracts) are likely to exist in the future.

In the subsections below, we assess the economic incentives for and implications of changes in the use of AMAs in the context of hypothetical restrictions on the use of AMAs given the current levels of AMA use and the current institutional structures within the pork industry.

7.2.1 Assessment of Economic Incentives for Increased or Decreased Use of AMAs

In this section, we summarize our findings related to the economic incentives for changes in the use of AMAs in the pork industry. This discussion is within the context of hypothetical restrictions on the use of AMAs.

Based on the survey results, producers and packers appear to have relatively few incentives to increase the use of AMAs beyond their current levels.

***Summary measure* of the economic incentives associated with use of AMAs.** Buyers and sellers of livestock and meat may have a number of different economic incentives associated with using AMAs or the cash market. Among pork producers that responded to the survey, the three most important reasons for selling their pigs and hogs using cash markets are

- independence—complete control and flexibility of own business (80% of respondents);
- ability to benefit from favorable market conditions (41%); and
- ability to sell pigs and hogs at higher prices (35%).

For the same group, the three most important reasons for using AMAs to sell pigs and hogs are

- the reduction in risk exposure (76% of respondents),
- the reduction in price variability (44%), and
- improvement in securing a buyer (39%).

For packers responding to the survey that only use cash or spot markets for procuring market hogs, the three most important reasons for doing so are

- independence—complete control and flexibility (60%);
- the ability to purchase hogs at lower prices (37%); and
- the ability to secure higher quality hogs (36%).

For packers responding to the survey that use AMAs for procuring market hogs, the three most important reasons for doing so are

- improvement in week-to-week supply management (62%),

- ability to secure higher quality market hogs (60%), and
- better market access (40%).

From these results, we can draw three conclusions. First, the push toward increased pork quality dictated by consumers is unlikely to produce any noticeable shift toward greater use of AMAs because views of different market participants about which marketing arrangement produces higher quality differ. Second, the incentives to stay independent and in full control of their own business counteract the risk-aversion considerations, with the direction of the net effect toward greater use of AMAs being ambiguous and likely very small. Finally, the only strong incentive towards greater use of AMAs seems to be the week-to-week supply management by packers.

Although a reduction in use of AMAs would lead to an improvement for hog producers through a reduction in the degree of market power, the loss in cost efficiencies offsets the gains from reduced market power.

***System-wide long-run effects* of major types of marketing arrangements on the livestock and meat industries.** To examine the long-run effects of AMAs, we calculated the economic implications of several hypothetical regulatory scenarios that would limit or completely eliminate access to one or more of the AMAs. Three types of simulations were performed: (1) 25% reduction in both contract and packer-owned hogs, (2) increase in the spot/cash market share to 25%, and (3) ban on packer ownership of hogs. The results show that, in the long run (10-year adjustment period), hog producers lose because of the offsetting effects of hogs diverted from AMA supplies to the spot market. In addition, consumers lose as wholesale and retail pork prices rise. Packers gain slightly in the first two scenarios but lose in the third scenario. The reason that producers and consumers lose in all three simulation scenarios is because of efficiency losses from reducing the proportion of hogs sold through contracts and/or packer owned channels. Although a reduction in use of AMAs would lead to an improvement for hog producers through a reduction in the degree of market power, the loss in cost efficiencies offsets the gains from reduced market power. In all instances, the price spread between farm and wholesale prices would be expected to increase because of the net increase in the costs of processing through reduction in AMAs.

The *most significant* types of spot market and alternative marketing arrangements based on the likelihood that the arrangement is or will be used extensively in the livestock and meat industries, including the types of

marketing arrangements that are likely to *grow in importance* and use and those that are likely to decrease in importance. Based on the industry survey of pork producers, pork packers, and meat processors, the following tendencies in the use of AMAs were identified:

- Pork producers used a variety of methods to sell pigs and hogs including the spot market, marketing agreements, marketing contracts, and production contracts. According to respondents, selling methods were very similar 3 years ago and are not expected to change within the next 3 years.
- Pork packers used a variety of methods to procure market hogs including the spot market, marketing agreements, marketing contracts, and production contracts. According to respondents, methods for purchasing market hogs were very similar 3 years ago and are not expected to change in the near future.
- The most common meat purchasing method by pork processors was the cash or spot market (less than 3 weeks forward), but some pork processors used forward contracts, marketing agreements and internal company transfers. The respondents expected these shares to be relatively stable over the next 3 years with perhaps a small increase in forward contracting.

We hypothesized that marketing arrangements may be complementary to each other in the sense that implementing one procurement practice may increase the marginal return of the other practice. However, the analyses of the complementarity of marketing arrangements produced inconclusive results.

Summary effects of *combinations of marketing arrangements* across different stages of the supply chain (e.g., used by a combination of producers, packers, retailers, food service operators, exporters). Based on the available data and the analyses conducted for the study, we can only draw general conclusions about the combinations of marketing arrangements used upstream. Based on the observation that packers use alternative marketing (procurement) arrangements in clusters (portfolios), we hypothesized that marketing arrangements may be complementary to each other in the sense that implementing one procurement practice may increase the marginal return of the other practice. However, the analyses of the complementarity of marketing arrangements produced inconclusive results. Although some simpler tests based on the correlation/association approach indicate that marketing contracts are in fact complementary to production contracts and/or packer owned arrangements, the portfolio coefficients in the performance equations based on either EBIT or gross margin do not monotonically increase with the portfolio order.

In other words, all marketing arrangements portfolios improve plant performance relative to the simple spot market purchases, but the three-marketing-arrangement portfolio effect is smaller than the two-marketing-arrangement portfolio effect. However, looking at the average price packers pay to procure their hogs, the results indicate that plants that use a combination of higher-order marketing arrangements on average pay lower prices for their hogs relative to plants that use the cash/spot market only. In addition, comparing the magnitudes of the portfolio effects with the magnitudes of the individual marketing arrangement effects shows that individual marketing arrangements have minimal additional impact on the average price (i.e., the portfolio system categorical variables capture almost the entire effect on lowering the average price).

Hypothetical restrictions on the use of AMAs would be expected to decrease consumer demand for pork because of reduced quality.

Major summary effects of AMAs on consumer demand. Consumer demand for meat is affected by the use of AMAs if those arrangements allow for the production of higher quality products and/or sale of pork products at lower prices. Based on the model simulations of reductions in using AMAs, we found a reduction in quantity demanded of all pork products as the average wholesale and retail prices of pork rise. The product mix of pork would be expected to shift away from loin and butts to ham and ribs under all scenarios. In addition, the analysis of the effects of AMAs on quality found that marketing contracts (especially other purchase arrangements and other market formula purchases) consistently yield higher quality hogs than negotiated (spot) purchases.

7.2.2 Implications of Expected Changes in Use of AMAs Over Time

In this subsection, we summarize our findings related to the implications of expected changes in the use of AMAs in the hog industry. This discussion is within the context of hypothetical restrictions on the use of AMAs.

Implications of changes in use of marketing arrangements on price discovery. Price discovery refers to the process by which a buyer and seller agree on a price for a specific transaction. Price discovery thus depends on the pricing method used for each type of marketing arrangement. The typical association between type of marketing arrangements and types of pricing methods in the hog and pork industries is as follows:

- Auction barns: auction pricing
- Direct trade and dealers/brokers: individually negotiated pricing
- Procurement or marketing contracts: formula pricing
- Forward contracts: formula pricing
- Marketing agreements: formula pricing
- Production contracts: compensation payment
- Packer ownership: internal transfer pricing

In the case of formula pricing, base prices are generally established based on publicly reported prices. For these types of transactions, the price reporting process is impeded only if the base price does not reflect current and expected supply and demand conditions. Because prices are reported under MPR for different types of marketing arrangements, the effect of the use of AMAs on the price discovery process is minimal.

Analyses of MPR and individual transactions data found that packers exercise some degree of market power in the procurement of live hogs. The MPR data analysis ties market power to the increased use of AMAs, whereas analysis of transactions data suggests that industry concentration might be a possible explanation of the source of market power.

Implications of expected changes in the use of marketing arrangements on *thin markets*. Markets are considered thin when the volume of transactions is so few that prices are highly volatile and transaction prices do not always reflect prices in other markets with the same quality of livestock or meat. Based on the individual transactions data, we found substantial intraday volatility in the spot market for live hogs. On average, the price dispersion is about 40% of the average value of the transaction prices each day. One part of this broad price dispersion can be explained by factors such as region, quality, or plant size. The rest must be due to organizational issues related to supply chain management or concentration in the pork processing sector. Statistical analyses of MPR data indicate that the wedge between spot price and unit returns from use of AMAs increases as the share of AMA supplies in hog slaughter increases, suggesting increased market power of packers. However, using the individual plant-level transaction data, the source of market power cannot be econometrically linked to use of AMAs for procuring live hogs, thus suggesting the traditional oligopsony story (concentration) as a possible explanation of the source of market power. The fact that spot prices are used extensively as the formula base for formula pricing in marketing contracts transmits the effect from the spot market to AMAs. The fact that increased use of AMAs may be the main source of market power transmits the effect from the AMAs to the spot market. Based on the completed analyses, the direction of the causality is ambiguous.

The most risky marketing arrangement for producers is the spot market, and the least risky marketing arrangement is production contracts.

Implications of expected changes in use of marketing arrangements on *risk management*. Different types of marketing arrangements exhibit different price volatilities; thus, they may subject the producers selling their hogs through these channels to different levels of risk. The most risky marketing arrangement for producers is the spot market, and the least risky marketing arrangement is production contracts. Regarding risk shifting associated with production contracts, we found that relative to the spot market, production contracts transfer about 94% of the total income variability from the contract grower to the integrator or packer. We also showed that producers who use production contracts are more risk averse than producers who use cash/marketing arrangements. This is consistent with the economic intuition that those economic agents who are more risk averse self-select themselves into less risky activities. Therefore, it is not surprising that economic losses associated with forcing producers to market their hogs through channels different from their risk-aversion-preferred marketing arrangement choice are substantial.

The competitiveness of pork relative to other meats, poultry, and fish will decline relative to a scenario without hypothetical restrictions on the use of AMAs.

Implications of expected changes in use of marketing arrangements on *competitiveness among meats*. Competitiveness among meats changes if prices or quality of products changes. Based on the simulations conducted in this volume, hypothetical restrictions on the use of AMAs decrease the quality and increase the price of pork products. Measures of the cross-price elasticities of demand between pork and other protein sources indicate that these products are substitutes. Thus, the competitiveness of pork relative to other meats, poultry, and fish will decline relative to a scenario without hypothetical restrictions on the use of AMAs.

Implications of expected changes in the use of marketing arrangements on *ease of entry* into each stage of the livestock and meat industries. One aspect of the problem of entry refers to whether individuals who would like to enter the business of producing and selling live hogs are easily able to do so. The other aspect refers to the ease of entry into pork packing. The ease of entry into the production of live hogs is affected by the availability of AMAs in a particular region. Historically, it has been well documented that spot markets

> The analyses conducted for this study show the industry exhibits decreasing average cost curves for a fairly wide range of outputs, thus indicating that entry may be difficult because any potential entrant will have to operate at a fairly large scale to be competitive.

were becoming thinner and that the importance of AMAs has grown over time. However, this trend seems to have stopped, and the industry interview responses and the industry survey results indicate that market participants are not expecting any major changes in the composition of procurement methods for live hogs in the near future. In terms of ease of entry into pork packing, the analyses conducted for this study show that the industry exhibits decreasing average cost curves for a fairly wide range of outputs. This indicates that entry may be difficult because any potential entrant will have to operate at a fairly large scale to be able to compete with the incumbents who will clearly have significant cost advantages as the consequence of their size.

Implications of expected changes in the use of marketing arrangements on *concentration* in livestock production and feeding and in meat packing, *structure* of the livestock industry, and *structure* of the meat packing industry. Based on the analyses conducted for this study, as well as the industry interviews and the survey results, we believe that changes in the use of AMAs in procuring live hogs will exert no significant impact on the pork industry's concentration and structure. However, given the fact that meat packing exhibits significant economies of scale and that larger plants are more likely to rely more heavily on AMAs to procure their hogs, the causality could be reversed. It is conceivable that the emergence of additional large plants might stimulate the change in the composition of procurement methods toward more significant reliance on AMAs and away from the spot markets, but the change would likely be small given that the spot market currently comprises only 11% of transactions.

8 References

Arora, A. and A. Gambardella. 1990. “Complementarity and External Linkages: The Strategies of the Large Firms in Biotechnology.” *Journal of Industrial Economics* 38:362-379.

Atkinson, S.E. and R. Halvorsen. 1984. “Parametric Efficiency Tests, Economies of Scale, and Input Demand in U.S. Electric Power Generation.” *International Economic Review* 25:647-662.

Azzam, A.M. 1997. “Measuring Market Power and Cost-Efficiency Effects of Industrial Concentration.” *Journal of Industrial Economics* 45:377-386.

Azzam, A.M. 1998. “Captive Supplies, Market Conduct, and the Open-Market Price.” *American Journal of Agricultural Economics* 80(1):76-83.

Bajari, P., H. Hong, and A. Khwaja. 2005. “A Semiparametric Analysis of Adverse Selection and Moral Hazard in the Demand for Health Insurance Contracts.” University of Michigan Working Paper. Ann Arbor, MI.

Barnett, W.A., and O. Seck. 2006. “Rotterdam vs. Almost Ideal Models: Will the Best Demand Specification Please Stand Up?” Unpublished paper, Lawrence, KS: University of Kansas, Department of Economics.

Barten, A.P. 1969. “Maximum Likelihood Estimation of a Complete System of Demand Equations.” *European Economic Review* 1:7-73.

Barten, A.P. 1977. “The System of Demand Functions Approach: A Review.” *Econometrica* 45:23-51.

Barten, A.P., and E. Geyskens. 1975. “The Negativity Condition in Consumer Demand.” *European Economic Review* 6:227-260.

Baye, M. R., J. Morgan and P. Scholten. 2005. “Information, Search and Price Dispersion.” *Handbook on Economics and Information Systems*, ed. T. Hendershott, Elsevier.

Berndt, E.R., and N.E. Savin. 1975. “Estimation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances.” *Econometrica* 43:937-957.

Bhuyan, S., and R.A. Lopez. 1997. “Oligopoly Power in the Food and Tobacco Industries.” *American Journal of Agricultural Economics* 79(1997):1035-1043.

Braulke, M. 1984. “The Firm in Short-Run Equilibrium: Comment.” *American Economic Review* 74:750-753.

Bullock, J.B. 2003. “Performance Evaluation of the U.S. Hog Slaughter Industry.” Department of Agricultural Economics Working Paper No. AEWP 2003-1. Columbia, MO: College of Agriculture, Food and Natural Resources at the University of Missouri-Columbia.

Cardon, J.H., and I. Hendel. 2001. “Asymmetric Information in Health Insurance: Evidence from the National Medical Expenditure Survey.” *RAND Journal of Economics*, 32(Autumn):408-427.

Chavas, J.P., and T.L. Cox. 1997. “On Market Equilibrium Analysis.” *American Journal of Agricultural Economics* 79(2):500-513.

Chen, Z., and R. Lent. 1992. “Supply Analysis in an Oligopsony Model.” *American Journal of Agricultural Economics* 74(4):973-979.

Christensen, L.R. and W. H. Greene. 1976. “Economies of Scale in U.S. Electric Power Generation.” *Journal of Political Economy* 84:655-676.

Cramer, J.S. 1973. “Interaction of Income and Price in Consumer Demand.” *International Economic Review* 14:351–363.

Dhrymes, P.J. 1970. “Equivalence of Iterative Aitken and Maximum Likelihood Estimates for a System of Regression Equations.” Unpublished, University of Pennsylvania.

Diewert, W.E. 1974. "Application of Duality Theory." In *Frontiers of Quantitative Economics*, M.D. Intriligator and D.A. Kendrick, eds. Amsterdam: North Holland.

Diewert, W.E. 1976. "Exact and Superlative Index Numbers." *Journal of Econometrics* 4:115-145.

Diewert, W.E., and T.J. Wales. 1988. "A Normalized Quadratic Semiflexible Functional Form." *Journal of Econometrics* 37:327-342.

Edgerton, D.L. 1997. "Weak Separability and the Estimation of Elasticities Multistage Demand Systems." *American Journal of Agricultural Economics* 79(1):62-79.

Engle, R.F., and C.W.J. Granger. 1987. "Cointegration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55:251-276.

Haley, M.M. November 2004. "Market Integration in the North American Hog Industries." United States Department of Agriculture, Economic Research Service. LDP-M-125-01.

Hanoch, G. 1975. "The Elasticity of Scale and the Shape of Average Costs." *American Economic Review* 65:492-97.

Heiner, R.A. 1982. "Theory of the Firm in 'Short-Run' Industry Equilibrium." *American Economic Review* 82:555-562.

Heiner, R.A. 1984. "Theory of the Firm in Short-Run Industry Equilibrium: Further Comment." *American Economic Review* 74:754.

Huang, K.S. 1993. "A Complete System of U.S. Demand for Food." U.S. Department of Agriculture, Economic Research Service, Technical Bulletin Number 1821. Washington, DC: USDA.

Ichniowski, C., K. Shaw and G. Prennushi. 1997. "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines." *The American Economic Review* 87(June):291-313.

Just, R.E., D.L. Hueth, and A. Schmitz. 1982. *Applied Welfare Economics and Public Policy*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Kadiyali, V. K. Sudhir, and V.R. Rao. 2001. "Structural Analysis of Competitive Behavior: New Empirical Industrial Methods in Marketing." *International Journal of Research in Marketing* 18:161-186.

Knoeber, C.R., and W.N. Thurman. 1995. "Don't Count Your Chickens...: Risk and Risk Shifting in the Broiler Industry." *American Journal of Agricultural Economics* 77:486-496.

Lawrence J.D., J. Kliebenstein, and M. Hayenga. January 1998. "How Iowa Compares to Other States. Iowa's Pork Industry—Dollars and Cents." Ames, IA: Iowa State University, Department of Economics.

Levinthal, D. 1997. "Adaptation on Rugged Landscapes." *Management Science* 43:943-950.

MacDuffie, J. 1995. "Human Resource Bundles and Manufacturing Performance: Organizational Logic and Flexible Production Systems in the World Auto Industry." *Industrial and Labor Relations Review* 48:197-221.

Mark, N.C., M. Ogaki, and K. Sul. 2005. "Dynamic Seemingly Unrelated Cointegrating Regressions." *Review of Economic Studies* 72:797-820.

Martin, L.L. 1994. "An Analysis of Vertical Coordination and Contracting in the North Carolina Pork Industry." Ph.D. Thesis, North Carolina State University, Raleigh, NC.

Milgrom, P., and J. Roberts. 1990. "The Economics of Modern Manufacturing: Technology, Strategy and Organization." *American Economic Review* 80: 511-528.

Miravete, E.J., and J.C. Pernias. 2006. "Innovation Complementarity and Scale of Production." *The Journal of Industrial Economics* 54 (March):1-29.

Mortimer, J.H. 2005. "Lecture 3: Demand Systems for Empirical Work in Industrial Organization (Part I)." Cambridge, MA: Harvard University.

Muth, M.K., G. Brester, J. Del Roccili, S. Koontz, B. Martin, N. Piggott, J. Taylor, T. Vukina, and M. Wohlgenant. July 2005. "Spot and Alternative Marketing Arrangements in the Livestock and Meat Industries: Interim Report." Prepared for the U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration. Research Triangle Park, NC: RTI International.

Nelson, J.A. 1991. "Quality Variation and Quantity Aggregation in Consumer Demand for Food." *American Journal of Agricultural Economics* 73:1204–1212.

Nerlove, M., and D.A. Bessler. 2001. “Expectations, Information and Dynamics.” *Handbook of Agricultural Economics, Volume 1.* B. Gardner and G. Rausser, eds., pp. 155-206, Amsterdam: Elsevier Science B.V.

Pennings, J.M.E., and A. Smidts. 2000. “Assessing the Construct Validity or Risk Attitude.” *Management Science* 46:1337-1348.

Pennings, J.M.E., and A. Smidts. 2003. “The Shape of the Utility Functions and Organizational Behavior.” *Management Science* 49:1252-1263.

Pennings, J.M.E., and B. Wansink. 2004. “Channel Contract Behavior: The Role of Risk Attitudes, Risk perceptions, and Channel Members’ Market Structures.” *Journal of Business* 77(4):697-723.

Phillips, P.C.B., and Loretan, M. 1991. “Estimating Long-Run Economic Equilibria.” *Review of Economic Studies* 58:407-436.

Porter, R. 1983. “A Study of Cartel Stability: The Joint Executive Committee, 1880-1886.” *Bell Journal of Economics* 14:301-314.

RTI International. 2005. Enhanced Facilities Database. Prepared for the U.S. Department of Agriculture, Food Safety and Inspection Service. Research Triangle Park, NC: RTI.

Schroeter, J.R. 1988. “Estimating the Degree of Market Power in the Beef Packing Industry.” *Review of Economics and Statistics* 70:158-162.

Sorensen, A. 2000. “Equilibrium Price Dispersion in Retail Markets for Prescription Drugs.” *Journal of Political Economy* 108:833-850.

Spinelli, P. November 1991. “Demand, Technology Shape U.S. Hog Industry—Trends in 1991 Hog Farming and Production.” In *Agricultural Outlook*, U.S. Department of Agriculture, Economic Research Service report.

Stigler, G. 1961. “The Economics of Information.” *Journal of Political Economy* 69:213-225.

Stock, J.H., and M.W. Watson. 1993. “A Simple Estimator of Cointegrating Vectors in Higher Order Integrated Systems.” *Econometrica* 61(4):783-820.

Theil, H. 1952-53. “Qualities, Prices and Budget Enquiries.” *Review of Economic Studies* 19:129-147.

Theil, H. 1971. *Principles of Econometrics.* New York: John Wiley & Sons, Inc.

Train, K. 1993. *Qualitative Choice Analysis. Theory, Econometrics, and an Application to Automobile Demand*. Cambridge, MA: The MIT Press.

U.S. Department of Agriculture. 2005. *Agricultural Statistics*. Washington, DC: National Agricultural Statistics Service.

U.S. Department of Agriculture, Agricultural Marketing Service. 2001–2005. *National Carlot Meat Trade Review: Meat, Livestock, and Slaughter Data, 2001–2005*.

U.S. Department of Agriculture, Economic Research Service. 2004. Hogs: Trade. <http://www.ers.usda.gov/Briefing/Hogs/trade.htm>. Last updated September 9, 2004.

U.S. Department of Agriculture, Economic Research Service, Market & Trade Economics Division. 2006. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA. <http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.>

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration. 2002. "Assessment of the Cattle and Hog Industries: Calendar Year 2001."<http://www.usda.gov/gipsa/pubs/01assessment/section3.pdf>. Last updated June 2002.

U.S. Department of Agriculture, Grain Inspection, Packers and Stockyards Administration. 2004. *Packers and Stockyards Statistical Report*. SR-06-1. Washington, DC: GIPSA.

U.S. Department of Agriculture, National Agricultural Statistics Services. December 1994. "Hogs and Pigs Final Estimates 1988-92." Agricultural Statistics Board. Statistical Bulletin Number 904.

U.S. Department of Agriculture, National Agricultural Statistics Services. December 1998. "Hogs and Pigs: Final Estimates by States 1993-97." Agricultural Statistics Board. Statistical Bulletin Number 951.

U.S. Department of Agriculture. National Agricultural Statistics Services. 2002. "U.S. Hog Breeding Herd Structure." Agricultural Statistics Board, September. <http://usda.mannlib.cornell.edu/reports/nassr/livestock/hog-herd/spehog02.pdf>. As obtained 2005.

U.S. Department of Agriculture, National Agricultural Statistics Service. 2004. “2002 Census of Agriculture.” Washington, DC: USDA. <http://www.nass.usda.gov/research/atlas02/>.

Walpole, R.E., and R.H. Myers. 1989. *Probability and Statistics for Engineers and Scientists*. 4th Ed. New York: MacMillan Publishing Co.

Ward, C.E. 2003. “An Appraisal of Expected Impacts from the Proposed Ban on Packers Owning Livestock.” Virginia Tech University, Research Institute on Livestock Pricing Research Paper. <http://www.aaec.vt.edu/rilp/Policy%20Papers%20Market%20Intervention/Clem%20Ward%20Paper.pdf>. As obtained in 2005.

Wohlgenant, M.K. 2001. “Marketing Margins: Empirical Analysis.” *Handbook of Agricultural Economics, Volume 1.* B. Gardner and G. Rausser, eds. Amsterdam: Elsevier Science B.V.

Wohlgenant, Michael K. 2005. “Market Modeling of the Effects of Adoption of New Swine Waste Management Technologies in North Carolina.” Prepared under the Economic Assessment of Alternative Swine Waste Management Systems: The Smithfield Foods-Premium Standard Farms Agreement with the North Carolina Attorney General, Department of Agricultural and Resource Economics, N.C. State University.

Xia, T. and R. J. Sexton. 2004. “The Competitive Implications of Top-of-the-Market and Related Contract-Pricing Clauses.” *American Journal of Agricultural Economics* 86:124-138.

Zheng, Z., T. Vukina, and C. Shin. 2006. “Regulating Packer Ownership of Live Hogs: The Impact on Farmers’ Welfare.” Unpublished paper, Department of Agricultural and Resource Economics, North Carolina State University, Raleigh, NC.

Appendix A: Summary of Hog Price Data from the Packer Transactions Data

Table A-1. Hog Price Summaries from Pork Packers' Transactions (Purchase) Data, October 2002–March 2005

	All Plants													
	$/cwt, Liveweight				$/cwt, Carcass Weight						Conversion Ratio =Carcass/Live weight			
Year/Week	(1) avg_hogp_3	Std. Dev. of (1)	(2) avg_basep_3	Std. Dev. of (2)	(3) avg_hogp_4	Std. Dev. of (3)	(4) avg_basep_4	Std. Dev. of (4)	Hog Price Ratio=(1)/(3)	Base Price Ratio=(2)/(4)	Pricing Unit=3	Pricing Unit=4	Converted Hog Price Using Pricing Units[a]	National Hogs Weighted Average Base Price (MPR)[b]
2002W40	38.81	5.35	37.83	5.50	44.88	5.87	42.63	5.94	0.86	0.89	0.73	0.75	48.66	42.3
2002W41	38.91	5.26	37.88	5.59	45.06	5.99	42.79	5.96	0.86	0.89	0.73	0.75	48.85	43.67
2002W42	35.56	5.38	34.57	5.75	42.36	6.76	40.13	6.42	0.84	0.86	0.71	0.75	45.53	43.56
2002W43	32.15	5.35	31.18	5.52	39.72	8.07	37.63	8.11	0.81	0.83	0.72	0.75	42.07	38.74
2002W44	34.54	5.71	33.42	5.48	41.37	7.50	39.32	7.63	0.83	0.85	0.73	0.75	44.23	35.58
2002W45	34.91	5.58	33.91	5.92	42.26	7.59	40.11	7.40	0.83	0.85	0.73	0.75	45.06	38.79
2002W46	33.86	5.17	32.75	5.29	41.04	7.58	38.93	7.52	0.83	0.84	0.73	0.75	43.70	38.32
2002W47	35.62	5.25	34.43	5.30	42.40	7.01	40.31	7.09	0.84	0.85	0.73	0.75	45.25	37.58
2002W48	37.67	5.20	36.60	5.36	44.48	6.68	42.40	6.60	0.85	0.86	0.73	0.75	47.55	39.86
2002W49	37.54	5.37	36.51	5.55	44.49	7.05	42.37	6.80	0.84	0.86	0.73	0.76	47.52	42.93
2002W50	36.69	5.38	35.71	5.51	43.87	6.96	41.72	6.76	0.84	0.86	0.73	0.76	46.47	41.76
2002W51	37.02	5.39	35.62	5.49	43.46	6.81	41.30	6.69	0.85	0.86	0.72	0.76	46.30	41.31
2002W52	37.09	5.15	35.93	5.53	44.06	6.54	41.88	6.51	0.84	0.86	0.73	0.76	46.85	40.83
2003W01	37.42	5.76	36.33	6.09	44.66	6.52	42.58	6.41	0.84	0.85	0.73	0.76	47.80	42.06
2003W02	39.22	5.00	38.21	5.32	45.24	5.75	42.99	5.57	0.87	0.89	0.72	0.76	49.09	42.25
2003W03	41.34	5.86	40.26	6.44	47.54	5.59	45.21	5.24	0.87	0.89	0.73	0.76	51.24	44.85
2003W04	41.28	5.69	40.17	5.85	47.50	5.85	45.11	5.34	0.87	0.89	0.74	0.76	51.50	46.87
2003W05	41.30	5.83	40.12	6.13	47.66	5.96	45.25	5.51	0.87	0.89	0.74	0.76	51.88	46.51
2003W06	40.98	5.40	40.00	5.80	47.65	6.21	45.23	5.70	0.86	0.88	0.73	0.76	51.45	46.6
2003W07	40.97	6.29	39.71	6.36	47.76	6.07	45.22	5.54	0.86	0.88	0.74	0.76	51.26	46.48
2003W08	40.43	5.49	39.40	5.79	47.09	5.93	44.60	5.56	0.86	0.88	0.73	0.76	50.87	46.35
2003W09	40.92	5.84	39.55	5.73	47.39	5.90	44.86	5.63	0.86	0.88	0.73	0.76	51.30	45.79
2003W10	41.31	6.00	40.11	5.95	48.10	5.64	45.60	5.48	0.86	0.88	0.73	0.76	52.02	46.3
2003W11	41.93	5.69	40.72	5.87	48.85	5.79	46.29	5.50	0.86	0.88	0.73	0.76	52.67	47.82
2003W12	42.35	5.38	41.11	5.77	48.86	6.01	46.35	5.63	0.87	0.89	0.73	0.76	52.97	48.38

(continued)

Table A-1. Hog Price Summaries from Pork Packers' Transactions (Purchase) Data, October 2002–March 2005 (continued)

	All Plants													
	$/cwt, Liveweight				$/cwt, Carcass Weight						Conversion Ratio =Carcass/Live weight			
Year/ Week	(1) avg_hogp_3	Std. Dev. of (1)	(2) avg_basep_3	Std. Dev. of (2)	(3) avg_hogp_4	Std. Dev. of (3)	(4) avg_basep_4	Std. Dev. of (4)	Hog Price Ratio=(1)/(3)	Base Price Ratio=(2)/(4)	Pricing Unit=3	Pricing Unit=4	Converted Hog Price Using Pricing Units[a]	National Hogs Weighted Average Base Price (MPR)[b]
2003W13	41.07	5.64	39.75	5.91	47.44	6.23	44.99	5.90	0.87	0.88	0.73	0.76	51.58	48.16
2003W14	41.21	5.50	40.26	5.64	48.09	6.03	45.68	5.74	0.86	0.88	0.73	0.76	52.19	46.15
2003W15	41.63	5.33	40.35	5.58	47.76	6.34	45.31	5.98	0.87	0.89	0.72	0.75	51.80	47.39
2003W16	42.12	5.93	41.27	6.07	49.51	5.41	46.95	5.22	0.85	0.88	0.72	0.76	53.21	46.28
2003W17	45.35	6.06	44.69	6.29	52.88	5.81	50.27	5.25	0.86	0.89	0.72	0.76	57.26	49.79
2003W18	47.54	5.70	46.86	6.01	54.36	5.59	51.80	5.12	0.87	0.90	0.72	0.76	59.16	52.94
2003W19	50.52	6.01	49.85	6.32	57.71	5.51	54.98	4.94	0.88	0.91	0.71	0.76	62.41	56.34
2003W20	52.38	6.69	51.76	6.95	59.66	6.23	57.03	5.41	0.88	0.91	0.73	0.76	64.79	59.41
2003W21	51.34	7.03	50.64	7.33	58.08	6.44	55.50	5.54	0.88	0.91	0.70	0.76	63.24	61.11
2003W22	52.02	6.47	51.25	6.87	59.45	5.85	56.89	5.24	0.87	0.90	0.72	0.76	64.64	58.23
2003W23	55.02	6.99	54.24	7.40	62.56	6.28	60.00	5.49	0.88	0.90	0.71	0.76	67.88	61.46
2003W24	55.79	6.96	55.03	7.36	63.29	6.49	60.71	5.69	0.88	0.91	0.73	0.76	68.66	64.95
2003W25	54.88	7.24	54.15	7.66	62.02	7.08	59.43	6.01	0.88	0.91	0.72	0.75	67.25	65.39
2003W26	51.98	6.82	51.15	7.21	59.38	6.34	56.87	5.48	0.88	0.90	0.72	0.76	64.09	63.05
2003W27	51.93	6.29	51.12	6.71	59.23	5.92	56.74	5.31	0.88	0.90	0.72	0.76	64.40	59.71
2003W28	50.66	6.38	49.93	6.83	57.94	6.07	55.66	5.41	0.87	0.90	0.72	0.76	62.80	60.72
2003W29	50.48	6.59	49.67	6.97	57.65	5.85	55.29	5.31	0.88	0.90	0.72	0.76	62.17	58.44
2003W30	49.85	6.20	49.13	6.60	57.03	5.88	54.62	5.31	0.87	0.90	0.72	0.76	61.83	58.77
2003W31	49.31	6.05	48.57	6.48	56.27	5.83	53.89	5.28	0.88	0.90	0.72	0.76	61.06	57.79
2003W32	49.30	6.15	48.57	6.53	56.55	5.75	54.18	5.18	0.87	0.90	0.72	0.76	61.24	56.84
2003W33	46.37	7.85	45.70	8.08	54.55	6.28	52.21	5.60	0.85	0.88	0.72	0.76	58.87	57.17
2003W34	44.54	6.20	43.88	6.62	51.79	6.65	49.41	6.01	0.86	0.89	0.72	0.76	55.60	53.33
2003W35	42.80	5.79	42.12	6.19	50.20	6.17	47.89	5.77	0.85	0.88	0.72	0.76	54.19	49
2003W36	46.31	6.14	45.63	6.56	53.65	5.22	51.28	5.05	0.86	0.89	0.72	0.75	58.83	48.32
2003W37	49.83	6.24	49.15	6.52	56.99	5.63	54.57	5.05	0.87	0.90	0.71	0.75	62.24	55.09
2003W38	49.90	6.48	49.24	6.79	57.20	6.55	54.83	5.66	0.87	0.90	0.72	0.75	62.34	58.59

(continued)

Table A-1. Hog Price Summaries from Pork Packers' Transactions (Purchase) Data, October 2002–March 2005 (continued)

	All Plants														
	$/cwt, Liveweight				$/cwt, Carcass Weight						Conversion Ratio =Carcass/Live weight			National Hogs Weighted Average Base Price (MPR)[b]
Year/ Week	(1) avg_hogp_3	Std. Dev. of (1)	(2) avg_basep_3	Std. Dev. of (2)	(3) avg_hogp_4	Std. Dev. of (3)	(4) avg_basep_4	Std. Dev. of (4)	Hog Price Ratio=(1)/(3)	Base Price Ratio=(2)/(4)	Pricing Unit=3	Pricing Unit=4	Converted Hog Price Using Pricing Units[a]	
2003W39	47.29	6.56	46.67	6.88	54.36	6.42	52.07	5.59	0.87	0.90	0.72	0.75	58.78	57.92
2003W40	45.36	6.00	44.66	6.26	52.60	6.01	50.29	5.49	0.86	0.89	0.72	0.75	56.55	53.52
2003W41	44.47	5.76	43.78	6.08	52.12	5.95	49.85	5.53	0.85	0.88	0.73	0.75	55.80	52.12
2003W42	43.69	6.07	43.04	6.33	50.88	6.44	48.67	5.91	0.86	0.88	0.73	0.76	54.41	51.76
2003W43	40.43	5.82	39.75	6.09	47.90	6.35	45.79	6.04	0.84	0.87	0.71	0.76	51.13	49.4
2003W44	40.73	5.85	40.13	6.04	48.27	5.69	46.14	5.69	0.84	0.87	0.73	0.76	51.99	46
2003W45	41.11	5.90	40.56	6.00	48.70	5.83	46.65	5.73	0.84	0.87	0.72	0.76	52.27	47.71
2003W46	40.66	5.60	40.04	5.83	48.16	5.92	46.08	5.86	0.84	0.87	0.72	0.76	51.47	47.86
2003W47	39.63	7.11	39.05	7.20	48.06	5.96	46.00	6.10	0.82	0.85	0.73	0.76	51.10	47.39
2003W48	41.33	5.70	40.72	5.98	48.66	5.99	46.56	5.97	0.85	0.87	0.73	0.76	51.95	47.34
2003W49	41.24	5.96	40.65	6.17	48.97	6.30	46.84	6.17	0.84	0.87	0.73	0.76	52.42	47.96
2003W50	41.28	5.77	40.61	5.89	48.81	6.40	46.65	6.39	0.85	0.87	0.73	0.76	51.93	47.71
2003W51	40.45	6.03	39.77	6.24	48.24	6.76	46.02	6.66	0.84	0.86	0.73	0.76	50.94	47.63
2003W52	40.99	5.86	40.31	6.05	48.55	6.02	46.34	6.13	0.84	0.87	0.73	0.76	51.73	45.96
2004W01	43.10	5.82	42.44	6.04	50.44	5.69	48.22	5.78	0.85	0.88	0.73	0.76	54.17	47.57
2004W02	43.02	6.01	42.39	6.18	50.49	5.88	48.21	5.86	0.85	0.88	0.73	0.76	53.80	50.15
2004W03	45.20	5.74	44.52	5.97	52.60	5.44	50.29	5.50	0.86	0.89	0.74	0.76	56.63	49.64
2004W04	47.90	5.71	47.25	6.06	55.02	5.52	52.58	5.32	0.87	0.90	0.74	0.76	59.40	53.74
2004W05	49.21	6.26	48.54	6.63	56.94	5.81	54.45	5.22	0.86	0.89	0.73	0.76	61.18	55.86
2004W06	52.12	6.65	51.45	7.02	59.95	6.12	57.36	5.47	0.87	0.90	0.74	0.76	64.86	58.05
2004W07	52.33	6.86	51.68	7.21	60.05	6.37	57.45	5.66	0.87	0.90	0.74	0.76	64.84	61.45
2004W08	51.32	6.44	50.61	6.84	59.02	6.29	56.41	5.66	0.87	0.90	0.73	0.76	63.24	60.93
2004W09	53.04	6.66	52.29	7.07	60.78	6.05	58.26	5.46	0.87	0.90	0.73	0.76	65.66	59.33
2004W10	53.76	6.96	53.03	7.36	61.58	6.44	59.03	5.72	0.87	0.90	0.74	0.76	66.51	62.67
2004W11	53.57	9.79	52.90	9.95	62.88	6.06	60.36	5.57	0.85	0.88	0.74	0.76	67.80	62.65
2004W12	56.53	7.10	55.83	7.52	64.31	6.59	61.75	5.86	0.88	0.90	0.74	0.76	69.52	65.52

(continued)

Table A-1. Hog Price Summaries from Pork Packers' Transactions (Purchase) Data, October 2002–March 2005 (continued)

	All Plants													
	$/cwt, Liveweight				$/cwt, Carcass Weight						Conversion Ratio =Carcass/Live weight			
Year/ Week	(1) avg_hogp_3	Std. Dev. of (1)	(2) avg_basep_3	Std. Dev. of (2)	(3) avg_hogp_4	Std. Dev. of (3)	(4) avg_basep_4	Std. Dev. of (4)	Hog Price Ratio=(1)/(3)	Base Price Ratio=(2)/(4)	Pricing Unit=3	Pricing Unit=4	Converted Hog Price Using Pricing Units[a]	National Hogs Weighted Average Base Price (MPR)[b]
2004W13	55.49	7.35	54.77	7.74	63.26	6.78	60.72	6.07	0.88	0.90	0.74	0.76	68.35	66.4
2004W14	52.74	7.34	52.05	7.77	60.65	6.87	58.09	6.15	0.87	0.90	0.73	0.76	64.95	64.24
2004W15	53.25	6.83	52.52	7.18	61.51	5.94	58.85	5.54	0.87	0.89	0.73	0.76	66.01	60.01
2004W16	55.89	6.68	55.08	7.23	64.12	6.28	61.47	5.81	0.87	0.90	0.73	0.76	68.78	63.22
2004W17	57.52	6.77	56.77	7.24	67.00	6.36	60.82	10.18	0.86	0.93	0.74	0.76	71.33	66.23
2004W18	61.01	7.79	60.26	8.25	71.62	6.60	67.75	6.80	0.85	0.89	0.73	0.76	75.54	69.62
2004W19	64.87	6.60	64.03	7.16	75.96	6.75	73.51	6.25	0.85	0.87	0.74	0.76	78.39	74.94
2004W20	65.88	7.38	65.04	7.96	78.38	8.00	75.95	7.26	0.84	0.86	0.74	0.76	79.44	80.25
2004W21	64.10	7.86	63.36	8.45	75.19	8.29	72.76	7.48	0.85	0.87	0.73	0.76	77.58	80.6
2004W22	62.30	7.80	61.56	8.37	72.16	7.23	69.71	6.53	0.86	0.88	0.74	0.76	75.93	76.11
2004W23	63.57	6.82	62.82	7.41	73.81	6.99	71.46	6.41	0.86	0.88	0.74	0.76	76.52	73.9
2004W24	64.54	7.39	63.76	7.99	74.98	7.64	72.59	6.86	0.86	0.88	0.74	0.76	77.46	76.97
2004W25	64.82	6.98	64.07	7.49	76.56	7.25	74.11	6.59	0.85	0.86	0.74	0.76	79.01	77.03
2004W26	64.74	7.76	64.04	8.25	75.64	8.10	73.21	7.17	0.86	0.87	0.74	0.76	78.08	79.73
2004W27	63.91	8.25	63.20	8.65	74.83	7.53	72.46	6.75	0.85	0.87	0.74	0.76	77.79	77.3
2004W28	64.79	7.57	64.06	8.11	75.15	7.32	72.69	6.70	0.86	0.88	0.73	0.76	77.46	76.95
2004W29	65.12	7.96	64.35	8.47	74.70	7.40	72.43	6.74	0.87	0.89	0.73	0.76	77.58	77.35
2004W30	64.70	7.54	63.98	8.02	74.88	7.30	72.55	6.68	0.86	0.88	0.74	0.76	77.46	77.04
2004W31	64.22	7.35	63.52	7.79	75.44	7.17	73.16	6.76	0.85	0.87	0.73	0.76	78.27	77.47
2004W32	64.91	8.13	64.14	8.65	75.00	7.62	72.82	7.00	0.87	0.88	0.74	0.76	77.05	77.79
2004W33	62.99	8.27	62.32	8.84	72.31	7.38	70.13	6.83	0.87	0.89	0.74	0.76	75.86	76.03
2004W34	60.96	7.37	60.24	7.90	70.16	6.88	68.13	6.40	0.87	0.88	0.74	0.76	74.58	72.86
2004W35	59.54	7.35	58.77	7.73	68.78	6.46	66.72	6.12	0.87	0.88	0.74	0.76	73.28	71.28
2004W36	59.66	7.90	58.84	8.25	68.20	6.48	66.14	6.08	0.87	0.89	0.73	0.76	72.50	70.56
2004W37	60.49	7.20	59.72	7.63	69.73	6.00	67.67	5.74	0.87	0.88	0.74	0.76	74.14	70
2004W38	63.46	6.11	62.68	6.63	74.38	6.16	72.22	6.10	0.85	0.87	0.73	0.76	76.79	74.02

(continued)

Table A-1. Hog Price Summaries from Pork Packers' Transactions (Purchase) Data, October 2002–March 2005 (continued)

	All Plants													
	$/cwt, Liveweight				$/cwt, Carcass Weight						Conversion Ratio =Carcass/Live weight			
Year/ Week	(1) avg_hogp_3	Std. Dev. of (1)	(2) avg_basep_3	Std. Dev. of (2)	(3) avg_hogp_4	Std. Dev. of (3)	(4) avg_basep_4	Std. Dev. of (4)	Hog Price Ratio=(1)/(3)	Base Price Ratio=(2)/(4)	Pricing Unit=3	Pricing Unit=4	Converted Hog Price Using Pricing Units[a]	National Hogs Weighted Average Base Price (MPR)[b]
2004W39	63.75	7.14	63.01	7.59	75.97	7.22	73.84	6.90	0.84	0.85	0.74	0.76	77.60	79.76
2004W40	64.07	8.08	63.26	8.64	73.42	7.87	71.37	7.20	0.87	0.89	0.73	0.76	76.04	78.67
2004W41	60.48	9.08	59.76	9.51	68.98	7.72	67.06	6.93	0.88	0.89	0.73	0.76	72.40	74.03
2004W42	58.66	7.83	57.98	8.28	66.62	6.56	64.68	5.91	0.88	0.90	0.74	0.76	71.00	68.51
2004W43	58.71	7.14	57.98	7.60	67.34	6.35	65.44	5.84	0.87	0.89	0.74	0.76	72.21	68.33
2004W44	60.47	7.25	59.80	7.71	69.12	5.81	67.23	5.54	0.87	0.89	0.74	0.76	72.98	70.01
2004W45	60.84	7.03	60.10	7.48	71.15	6.61	69.37	6.16	0.86	0.87	0.74	0.76	74.16	73.96
2004W46	61.77	7.00	60.99	7.42	73.29	6.50	71.53	6.06	0.84	0.85	0.74	0.76	75.90	74.64
2004W47	62.14	7.59	61.35	8.02	73.47	7.30	71.61	6.63	0.85	0.86	0.74	0.76	75.76	77.67
2004W48	63.26	7.17	62.46	7.62	74.87	6.50	73.10	6.09	0.84	0.85	0.74	0.76	77.38	75.78
2004W49	63.63	7.49	62.97	7.97	74.79	7.94	73.10	7.31	0.85	0.86	0.74	0.76	76.35	80.33
2004W50	57.57	10.73	56.92	10.95	68.53	8.32	66.80	7.48	0.84	0.85	0.74	0.76	71.24	76
2004W51	53.46	10.68	52.79	10.94	63.14	7.32	61.37	6.54	0.85	0.86	0.74	0.76	67.40	67.39
2004W52	54.83	6.95	54.11	7.52	61.58	5.57	59.73	5.18	0.89	0.91	0.74	0.76	65.53	62.27
2005W01	57.59	7.06	56.85	7.48	65.92	5.37	64.05	5.32	0.87	0.89	0.74	0.76	70.12	63.68
2005W02	58.66	8.26	57.91	8.70	68.41	6.43	66.52	5.96	0.86	0.87	0.74	0.76	72.63	70.58
2005W03	60.88	7.52	60.08	8.06	69.60	6.20	67.72	5.85	0.87	0.89	0.74	0.76	73.65	70.23
2005W04	61.22	7.56	60.42	8.11	70.69	6.36	68.83	6.08	0.87	0.88	0.74	0.76	74.27	72.56
2005W05	60.61	8.01	59.76	8.61	70.12	7.04	68.11	6.60	0.86	0.88	0.75	0.76	73.86	73.75
2005W06	57.44	7.94	56.64	8.51	66.39	7.27	64.32	6.76	0.87	0.88	0.74	0.76	70.16	71.13
2005W07	55.77	6.93	54.94	7.53	64.28	6.04	62.26	5.71	0.87	0.88	0.74	0.76	68.51	65.61
2005W08	57.78	6.96	56.97	7.51	66.26	5.69	64.20	5.49	0.87	0.89	0.74	0.76	70.56	65.94
2005W09	58.86	7.00	57.97	7.59	66.96	5.76	64.94	5.64	0.88	0.89	0.74	0.76	71.27	69.45
2005W10	61.04	6.76	60.16	7.46	69.85	5.88	67.76	5.89	0.87	0.89	0.74	0.76	73.38	70.45
2005W11	57.79	7.76	56.96	8.37	66.99	7.36	64.96	6.79	0.86	0.88	0.74	0.76	70.13	73.75
2005W12	56.56	7.20	55.79	7.73	65.06	6.14	63.03	5.88	0.87	0.89	0.74	0.76	68.94	66.18

(continued)

Table A-1. Hog Price Summaries from Pork Packers' Transactions (Purchase) Data, October 2002–March 2005 (continued)

	All Plants												Converted Hog Price Using Pricing Units[a]	National Hogs Weighted Average Base Price (MPR)[b]
	$/cwt, Liveweight				$/cwt, Carcass Weight						Conversion Ratio =Carcass/Live weight			
Year/ Week	(1) avg_hogp_3	Std. Dev. of (1)	(2) avg_basep_3	Std. Dev. of (2)	(3) avg_hogp_4	Std. Dev. of (3)	(4) avg_basep_4	Std. Dev. of (4)	Hog Price Ratio=(1)/(3)	Base Price Ratio=(2)/(4)	Pricing Unit=3	Pricing Unit=4		
2005W13	55.58	7.16	54.83	7.67	64.00	6.14	62.04	5.81	0.87	0.88	0.75	0.76	68.25	66.33
Average	50.94	6.66	50.13	7.02	59.14	6.46	56.84	6.07	0.86	0.88	0.73	0.76	62.90	59.56

[a] Simple weekly average of converted hog price ($/cwt, carcass weight) using the pricing unit variable provided in the pork packers' transaction data set.

[b] From various issues (2002, 2003, 2004, and 2005) of *Annual (Carlot) Meat Trade Review: Meat, Livestock & Slaughter Data*, USDA.

Table A-2. Testing the Hypothesis of Same Means for Three Price Series: Two-Sample Equal Mean t-test (H_o: difference=0 vs. H_a: difference ≠0)

Difference	t value	P value
mean(*avg_basep_4*) – mean(*mpr_p*)[a]	–1.86	.0634
mean(*avg_basep_4*) – mean(*convert_p*)	–4.54	.0000
mean(*convert_p*) – mean(*mpr_p*)	2.31	.0219

[a] We cannot reject the null hypothesis of equal means at the 5% significance level.

Table A-3. Correlation Coefficient Analysis for Three Price Series[a]

Variable	***avg_basep_4***	***convert_p***	***mpr_p***
avg_basep_4	1	0.9946	0.9891
convert_p	—	1	0.9850
mpr_p	—	—	1

[a] All P values are less than .0001.

B Economic Effects of Restricting AMAs in the Hog and Pork Industries

In this appendix, we present a model for estimating the economic effects associated with restricting marketing arrangements used in the hog and pork industries. We use the results of this modeling exercise in Sections 2, 3, and 6 of this report volume.

B.1 MODEL SPECIFICATION

The model to be used for estimation assumes that all commodities produced and all raw materials procured are homogenous. The profit function of the *i*th firm is

$$\pi^i = \sum_{j=1}^{J} P_j(Y_1, Y_2, \ldots, Y_J)Y_j^i - C^i(Y_1^i, Y_2^i, \ldots, Y_J^i, X_1^i, X_2^i, \ldots, X_K^i, \mathbf{W}^-) - \sum_{k=1}^{K} W_k(X_1, X_2, \ldots, X_K)X_k^i, \tag{B.1}$$

where price of the *j*th output is P_j, quantity of firm *i*'s *j*th output is Y_j^i, W_k is the price of the raw material from the *k*th source, X_k^i is the quantity of the raw material purchased by the *i*th firm from source *k*, $P_j(Y_1, Y_2, \ldots, Y_J)$ is the demand function for output *j* facing each firm in the industry, $W_k(X_1, X_2, \ldots, X_K)$ is the supply function for raw material source *k* facing each firm in the industry, $C^i(Y_1^i, Y_2^i, \ldots, Y_J^i, X_1^i, X_2^i, \ldots, X_K^i, \mathbf{W}^-)$ is the cost function of the *i*th firm, and $\mathbf{W}^-$ represents the vector of variable input prices other than the raw material (e.g., labor, packaging, energy, transportation).

The cost function is derived from the general implicit production function, $F^i(Y_1^i, Y_2^i, \ldots, Y_J^i; X_1^i, X_2^i, \ldots, X_K^i; \mathbf{Z}) = 0$, where $\mathbf{Z}$ represents the vector of input quantities other than the raw material.

The first-order conditions (f.o.c.) for profit maximization under Cournot-Nash equilibrium are as follows[1]:

$$\begin{aligned}
\frac{\partial \pi^i}{\partial Y_j^i} &= P_j + \frac{\partial P_j}{\partial Y_j} Y_j^i - \frac{\partial C^i}{\partial Y_j^i} = 0 \\
\frac{\partial \pi^i}{\partial X_k^i} &= -\frac{\partial C^i}{\partial X_k^i} - W_k - \frac{\partial W_k}{\partial X_k} X_k^i = 0 .
\end{aligned} \tag{B.2}$$

These conditions hold for $j = 1,\ldots,J; k = 1,\ldots,K; i = 1,\ldots,N.$ Note also that

$$Y_j = \sum_i Y_j^i, \; X_k = \sum_i X_k^i .$$

The first set of equations in Eq. (B.2) shows the relationship between price and marginal cost of each firm's output production decision. Marginal revenue equals marginal cost, with marginal revenue consisting of the sum of the output price and marginal effect of the output on the output price from changes in the firm's output. The second set of equations in Eq. (B.2) shows the relationship between the raw product price from different sources and the firm's marginal input costs. If the firm can influence the price of the raw material through changes in its input purchases, the input price will change in response to a change in the firm's input purchase. In both cases of output and input decisions, these specifications show that there can be a wedge between price and marginal cost. In the case of output price, price could be above marginal cost. For input decisions, the raw material price could be below its marginal cost to the firm.

For empirical work, functional forms must be chosen for the cost function and the demand and supply functions. If the demand and raw material supply functions are linear and the cost function is quadratic, then the f.o.c. given by Eq. (B.2) can be represented as follows:

[1] For simplicity, we assumed the firm ignores the influence of other output quantities on own output price and other input quantities on own input price. Making the model more complete by including those cross-quantity effects only complicates the analysis without adding any new insights or different restrictions on the model.

$$P_j - b_{jj}^i Y_j^i - \sum_{l \neq j} b_{jl}^i Y_l^i - \sum_k c_{jk}^i X_k^i = 0 \qquad \text{(B.3)}$$

$$W_k + \sum_j c_{kj}^i Y_j^i + a_{kk}^i X_k^i + \sum_{m \neq k} a_{mk}^i X_m^i = 0 \quad .$$

The reduced-form f.o.c. in Eq. (B.3), which are derived assuming Cournot behavior, actually depict more general behavior than Cournot. Kadiyali, Sudhir, and Rao (2001) show that under certain conditions the same behavior could result from Bertrand, leader-follower, or collusive behavior. More generally, the conjectural variations framework would also fit into this framework, provided that the Herfindahl index did not change markedly during the sample period. Therefore, the reduced-form f.o.c. in Eq. (B.3) can be taken to represent many alternative market structures.[2] *The significance of this result for this study is that the economic surplus effects account both for any market power effects and for changes in efficiencies resulting from changes in the mix of marketing arrangements.*

For estimation purposes, error terms can be attached to the equations to obtain

$$P_j = \left(b_{jj}^i Y_j^i + \sum_{l \neq j} b_{jl}^i Y_l^i + \sum_k c_{jk}^i X_k^i \right) + \varepsilon_j^i \qquad \text{(B.4a)}$$

$$W_k = -\left(\sum_j c_{kj}^i Y_j^i + a_{kk}^i X_k^i + \sum_{m \neq k} a_{mk}^i X_m^i \right) + \varepsilon_k^i \quad , \qquad \text{(B.4b)}$$

where ε_j and ε_k are error terms.[3] Note that the output price and input price specifications have cross-equation restrictions. Therefore, these equations should be estimated as a system of equations with appropriate assumptions on the error terms.

In the empirical application to secondary data, we require aggregate specifications for the equations in Eq. (B.4a) and Eq. (B.4b). After summing across all firms (and dividing by the number of firms [*N*]), we obtain

[2] Note that when there is price-taking behavior, the coefficients directly represent parameters of the cost function.

[3] For sake of presentation, other variable input prices are not included in these equations. They should and could be accounted for in various ways. In the empirical application that follows, no data exist for these variables, but we attempted to control for these effects by including a trend variable and monthly binary variables in the model.

$$\begin{aligned} P_j &= b_{jj}Y_j + \sum_{l \neq j} b_{jl}Y_l + \sum_k c_{jk}X_k + \varepsilon_j \\ &+ \sum_l \sum_i (Y_l^i - \overline{Y}_l)[b_{jl}^i(Y_l^i / Y_l) - b_{jl}] / N \\ &+ \sum_k \sum_i (X_k^i - \overline{X}_k)[c_{jk}^i(X_k^i / X_k) - c_{jk}] / N \end{aligned} \tag{B.5a}$$

$$\begin{aligned} W_k &= -\left(\sum_j c_{kj}Y_j + a_{kk}X_k + \sum_{m \neq k} a_{mk}X_m \right) + \varepsilon_k \\ &- \sum_j \sum_i (Y_j^i - \overline{Y}_j)[c_{kj}^i(Y_j^i / Y_j) - c_{kj}] / N \\ &- \sum_m \sum_i (X_m^i - \overline{X}_m)[a_{mk}^i(X_m^i / X_m) - a_{mk}] / N , \end{aligned} \tag{B.5b}$$

where the *a*'s, *b*'s, and *c*'s are average response parameters of all firms in the industry; $\varepsilon_j = \sum_i \varepsilon_j^i / N$ and $\varepsilon_k = \sum_i \varepsilon_k^i / N$. The additional terms on the right-hand sides of Eqs. (B.5a) and (B.5b) can be viewed as covariances between coefficients of individual firms and the quantities of outputs and inputs selected by the firm. If Y_l^i and b_{jl}^i are stochastic and independent, then the $\mathrm{cov}(Y_l^i, b_{jl}^i) = 0$. Likewise, if X_k^i and c_{jk}^i are independent, then the covariance between these two variables will also be zero. In the same way, we might expect the covariances between Y_j^i and c_{kj}^i and between X_m^i and a_{mk}^i to be zero.

If the above stochastic assumptions hold, then the aggregate counterparts to Eqs. (B.4a) and (B.4b) are simply[4]

$$P_j = b_{jj}Y_j + \sum_{l \neq j} b_{jl}Y_l + \sum_k c_{jk}X_k + \varepsilon_j \tag{B.6a}$$

$$W_k = -\left(\sum_j c_{kj}Y_j + a_{kk}X_k + \sum_{m \neq k} a_{mk}X_m \right) + \varepsilon_k \ . \tag{B.6b}$$

Therefore, we can view the aggregate-level relationships in every respect as if they represented the average response of all firms in the industry.[5] Aside from the own-quantity variables, the other parameters in Eqs. (B.6a) and (B.6b) correspond to

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[4] See Theil (1971, p. 572) for more discussion about the convergence approach to aggregation.

[5] For the data used below, this seems very reasonable because the carlot data on pork cuts are sales of a random sample of firms each week. The MPR data may be viewed as stochastic as well. In both instances, the validity of aggregation hinges on whether firm-level marginal costs do not vary systematically with size of the firm.

the aggregate cost function. If market power is present, then the own-quantity variables reflect the effects of both imperfect competition and curvature of the cost function.

Eqs. (B.6a) and (B.6b) involve a large number of parameters, even for a moderate-sized industry. In the pork industry, there are six primal cuts and three sources of hogs. Even with the symmetry restrictions imposed, this still represents a large number of parameters to estimate. The number of parameters to estimate can be significantly reduced by assuming the aggregate production function is separable in outputs and inputs; that is,

$$F(\mathbf{Y}) = H[G(\boldsymbol{X}), I(\mathbf{Z})] \ . \qquad \text{(B.7)}$$

With the production function indicated by Eq. (B.7), the aggregate cost function corresponding to the average representative firm can be represented as

$$C = C(\mathbf{Y}, \mathbf{X}, \mathbf{W}^-) = C^*[F(\mathbf{Y}), G(\mathbf{X}), \mathbf{W}^-] \ . \qquad \text{(B.8)}$$

When the cost function has the quadratic form as indicated in Eq. (B.8), where the functions $F(\mathbf{Y})$ and $G(\mathbf{X})$ are each quadratic linearly homogenous functions, the aggregator functions can be exactly represented by the Fisher Ideal quantity indexes (Diewert, 1976),

$$Y_{Id}(\mathbf{P}^0, \mathbf{P}^1; \mathbf{Y}^0, \mathbf{Y}^1) = [\mathbf{P}^1 \bullet \mathbf{Y}^1 \mathbf{P}^0 \bullet \mathbf{Y}^1 / \mathbf{P}^1 \bullet \mathbf{Y}^0 \mathbf{P}^0 \bullet \mathbf{Y}^0]^{1/2} \qquad \text{(B.9a)}$$

$$X_{Id}(\mathbf{W}^0, \mathbf{W}^1; \mathbf{X}^0, \mathbf{X}^1) = [\mathbf{W}^1 \bullet \mathbf{X}^1 \mathbf{W}^0 \bullet \mathbf{X}^1 / \mathbf{W}^1 \bullet \mathbf{X}^0 \mathbf{W}^0 \bullet \mathbf{X}^0]^{1/2} \ , \qquad \text{(B.9b)}$$

and one does not have to estimate the unknown parameters in the aggregator functions $F(\mathbf{Y})$ and $G(\mathbf{X})$.[6]

The implication of the specification indicated by Eq. (B.8) is that the estimating equations can be written with raw materials in Eq. (B.6a) replaced with the aggregator function Eq. (B.9b) and

[6] The aggregator functions for a quadratic form are square root functions of quadratic functions of the components within the aggregator functions.

the pork primals in Eq. (B.6b) replaced with the aggregator function Eq. (B.9a). The new specification becomes[7]

$$P_j = b_{jj}Y_j + \sum_{l \neq j} b_{jl}Y_l + c_j X_{Id} + \varepsilon_j \qquad \text{(B.10a)}$$

$$W_k = d_k Y_{Id} - a_{kk}X_k - \sum_{m \neq k} a_{mk}X_m + \varepsilon_k \;. \qquad \text{(B.10b)}$$

In addition to conserving degrees of freedom, this specification of packer behavior allows us to separate the input decisions from the output decisions. That is, given total pork output (or anticipated pork demand), packers may be viewed as choosing the mix of raw materials given the prices of the inputs. Alternatively, with the quantities of the hogs to be slaughtered predetermined in the current period, the equations shown in Eq. (B.10b) represent the market prices given the quantities of hogs marketed and the expected pork demand. Likewise, prices of primal cuts in Eq. (B.10a) would be determined by relative quantities of cuts produced given the available supply of pork from hogs slaughtered. In the above specification, we would expect the matrix of parameters associated with the output variables in Eq. (B.10a) to be positive semidefinite and the matrix of parameters associated with the input quantities in Eq. (B.10b) to be negative semidefinite (equivalently, the matrix of the a_{km}'s to be positive semidefinite). We also expect $c_j < 0$ and $d_k > 0$.

The demand functions facing packers are derived demand functions for the commodities ultimately purchased by consumers. Conceptually, these demand functions take into

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[7] Note that the f.o.c. for profit maximization with the aggregate cost function Eq. (B.8) become

$$P_j + \frac{\partial P_j}{\partial Y_j}Y_j - \frac{\partial C}{\partial Y_j}Y_j = P_j + \frac{\partial P_j}{\partial Y_j}Y_j - \frac{\partial C^*}{\partial F}\frac{\partial F}{\partial Y_j} = 0$$

.

$$-\frac{\partial C}{\partial X_k} - W_k - \frac{\partial W_k}{\partial X_k}X_k = -\frac{\partial C^*}{\partial G}\frac{\partial G}{\partial X_k} - W_k - \frac{\partial W_k}{\partial X_k}X_k = 0$$

Because the first set of equations depends only on the aggregator function *G* in addition to the *Y* variables, we can express these equations as shown by Eq. (B.10a). Likewise, the second set of f.o.c. only depends on the aggregator function *F* in addition to the *X*s, so these equations can be expressed in the form shown in Eq. (B.10b). The specifications shown by Eqs. (B.10a) and (B.10b) are less restrictive than that implied by the separable form of the cost function, because the model does not impose the separability restriction that $\frac{\partial C / \partial Y_j}{\partial C / \partial Y_l} = \psi(\mathbf{Y})$ and $\frac{\partial C / \partial X_k}{\partial C / \partial X_m} = \xi(X)$.

account all downstream effects of changes occurring in upstream markets. Although the systems of the demand functions approach can still be appropriate in modeling demand for these commodities, it is important to allow for appropriate modifications. In particular, these demand functions are homogenous of degree zero in income and all input prices—raw material input prices and nonraw material input prices. Therefore, in estimating such a system of demand functions without all input prices included, the homogeneity restrictions may not hold. However, the symmetry restrictions may still hold (Chavas and Cox, 1997).[8]

The approach taken here is similar to the approach of Hausman (Mortimer, 2005). In this approach, we assume a two-stage budgeting process. In the first stage, the consumer chooses between pork and all other goods. In the second stage, given expenditures on pork products, the consumer chooses among the different pork products.

Initially, the almost ideal demand system (AIDS) model was chosen. Although convergence was achieved and the own-price elasticities were found to be negative at the majority of the observations, it failed to satisfy negative semidefiniteness at any data point and produced implausible elasticities in many instances. Correction was made for estimation of first-order autocorrelation in the residuals, but that approach failed to change the results materially.[9]

A viable alternative functional form to the AIDS model is the absolute price version of the Rotterdam Model (RM). This model can be specified as follows:

$$\bar{S}_j \Delta \log Y_j = a_j + \sum_{k=1}^{n} b_{jk} \Delta \log P_j + c_j \Delta \log X \ , \qquad \text{(B.11)}$$

where $\bar{S}_j$ is the average budget share between intervening periods (weeks in this case), and $\Delta \log X = \sum_j \bar{S}_j d \log Y_j$ is the relative change in real total expenditures on pork in the current period. The notation "Δ" denotes change and refers to change in the variable from the previous week to the current week. Symmetry holds when $b_{jk} = b_{kj}$. Also, if homogeneity holds,

[8] See Attachment 1 of this appendix, "Specification of Derived Demand for Pork Cuts," for a discussion of these points.

[9] Estimation was conducted by Piggott.

then $\sum_k b_{jk} = 0 \forall j$. Of course, as indicated before, there is reason to believe that this restriction will not hold, so one should only impose the homogeneity restriction if it is not rejected statistically. Finally, the matrix of parameters (b_{jk}) is expected to be negative-definite. In support of the RM, Barnett and Seck (2006) have shown that the RM clearly dominates the AIDS in cases where there can be high substitutability among goods, which one would expect to be the case here. Overall, the RM seems to do a better job of approximating unknown price elasticities than the AIDS model in conditional demand functions.

Supply of hogs from each source is assumed to be predetermined in each week because decisions on number of pigs to slaughter in a given week are made previous to that week. Also, because of tight scheduling problems, there is little or no opportunity to move slaughter from 1 week to the other in response to changes in economic conditions. Therefore, supplies can be viewed as perfectly inelastic with respect to market prices within the current week (Bullock, 2003).

B.2 PORK INDUSTRY DATA

Pork data were obtained from USDA, AMS, *National Carlot Meat Trade Review: Meat, Livestock, and Slaughter Data*, 2001–2005. We aggregated the data to weekly amounts. The quantity data are presented in number of carlots (40,000-pound lots). The proportions of each cut (loin, butt, ham, picnic, belly, rib) were multiplied by average weekly U.S. pork production to obtain thousands of pounds marketed. Table B-1 summarizes the data.

Hog data are MPR data provided by USDA, AMS. The data are provided for August 10, 2001, through September 30, 2005, on a weekly basis.[10] The six types of marketing instruments are (1) negotiated purchases, (2) other market formula purchases (based on formula price other than the market for hogs, pork, or a pork product; formula may be based on one or more futures or options contracts), (3) swine or pork market formula purchases (formula price based on market for swine, pork, or a

[10] The same aggregation procedure is followed as for estimating aggregate quantities—proportions of head in each category are multiplied by the average pork production per week.

Table B-1. Summary Statistics of Weekly Pork Primal Cuts: Slaughter Values and Quantities, August 10, 2001–September 30, 2005

Variable	N	Mean	Std Dev
p_loin	217	79.9664516	10.1727399
p_butt	217	59.2835945	12.5855802
p_ham	217	50.3645161	12.2033613
p_rib	217	122.0556682	17.1121195
p_belly	217	83.9891705	14.4318368
p_picnic	217	40.8767281	11.1189015
loin_lbs	217	110.3752063	30.6538388
butt_lbs	217	58.3497952	18.3915121
ham_lbs	217	94.3521645	26.9974187
rib_lbs	217	12.5418756	6.9529211
belly_lbs	217	21.7612271	14.2663447
picnic_lbs	217	29.5053996	10.0565297

Note: Values are in $/cwt, and quantities are in 1,000 lbs.

pork product), (4) other purchase arrangements (including long-term contract agreements, fixed-price contracts, cost of production formulas), (5) packer sold (sold for slaughter to another packer), and (6) packer owned (hogs owned by packer for at least 14 days before slaughter). Price data were available only for the first through fifth instruments because packer-owned hogs were not traded. The fifth instrument, hogs owned by packers, is viewed as an intermediate input and is therefore not included in the empirical model. However, the price of packer-sold hogs is taken to be the imputed price of packer-owned hogs because this price is a measure of the opportunity cost of hogs owned by packers. For econometric analysis, all marketing instruments (instruments 2 through 4) are aggregated together. The quantity index is the Fisher Ideal index multiplied by the sample mean average of quantities for this category. The price index is obtained by dividing total value by the quantity index. Summary statistics of the three marketing arrangements used in the econometric analysis (negotiated, contracted, and packer owned) are shown in Table B-2.

Table B-2. Summary Statistics of Weekly Mandatory Hog Prices and Quantities, August 10, 2001–September 30, 2005

Variable	N	Mean	Std Dev
p_neg	217	59.4053610	12.1348986
p_con	217	60.3493519	9.7093267
p_own	217	63.1364716	11.8053015
neg_lbs	217	50.4345681	8.6589549
con_lbs	217	257.7430445	21.3350240
own_lbs	217	72.8061901	8.6881661

Note: See Table B-1.

B.3 ECONOMETRIC SPECIFICATION

The reduced-form f.o.c. of packer behavior, Eqs. (B.10a) and (B.10b), are estimated using the DSUR method (Mark, Ogaki, and Sul, 2005). DSUR is an especially appropriate method when transient dynamics and endogeneity jointly can make it difficult to estimate standard dynamic simultaneous equation models. The approach posits the existence of long-run relationships between prices and quantities in the case of the packer f.o.c. If unit roots are present in the variables, which is the case here, then establishing a cointegrating relationship among the variables of interest is necessary. From an economic point of view, the goal is to estimate the long-run or steady-state relationship. Error correction models have often been proposed as the best vehicle to achieve this goal, and they are advantageous because short-run dynamics, regardless of the source, can be controlled for in estimation. One of the problems with a strictly error-correction model is the problem of endogeneity. If the variables on the right-hand side are not strictly exogenous, traditional estimation methods may produce inconsistent results. One could use an instrumental variable approach, but selecting the best instruments becomes problematic. The method of DSUR introduced by Mark, Ogaki, and Sul (2005) extends previous methods by correcting for endogeneity while also controlling for transient dynamics and unit roots.

Endogeneity and dynamics are controlled for by introducing lag and lead variables in each equation estimated. For the packer behavioral equations, the equations to estimate become

$$\begin{aligned} P_{jt} &= b_{jj} Y_{jt} + \sum_{l \neq j} b_{jl} Y_{lt} + c_j X_{Idt} \\ &\sum_l \sum_r d_{jl}^r \Delta Y_{jt-r} + \sum_l \sum_s d_{jl}^s \Delta Y_{jt+s} \\ &\sum_j \sum_r e_{jk}^r \Delta X_{kt-r} + \sum_j \sum_s e_{jk}^s \Delta X_{kt+s} + \varepsilon_{jt} \end{aligned} \tag{B.12a}$$

$$\begin{aligned} W_{kt} &= d_k Y_{Idt} - a_{kk} X_{kt} - \sum_{m \neq k} a_{mk} X_{mt} + \\ &\sum_j \sum_r f_{kj}^r \Delta Y_{jt-r} + \sum_j \sum_s f_{kj}^s \Delta Y_{jt+s} \\ &\sum_m \sum_r f_{mk}^r \Delta X_{kt-r} + \sum_l \sum_s f_{mk}^s \Delta X_{kt+s} + \varepsilon_{kt} \ , \end{aligned} \tag{B.12b}$$

where *r* and *s* denote lags and leads of first differences of the quantities of outputs and quantities of marketing arrangements.

The set of equations in Eqs. (B.12a) and (B.12b) were estimated by DSUR assuming $r = s = 3$.[11] To account for seasonal effects, monthly binary variables are included in the model. A linear time trend is also included in the model to account for the effects of unobserved changes in other variable input prices.

The packer behavioral equations were estimated in two sets: (1) input decisions given (expected) output of pork and (2) output prices given supplies of pork available from hogs. Following the approach of Mark, Ogaki, and Sul (2005) each model was estimated in two steps. In the first step, all the dependent and right-hand side variables were regressed on the lags and leads of the first differences of the quantities of outputs and quantities of marketing arrangements to purge the variables of endogeneity and transient dynamics. In the second step, the residuals from the first step were used in estimation by the seemingly unrelated regression (SUR) method. Mark, Ogaki, and Sul (2005) proved that this approach is equivalent to estimating the complete model in one step. In addition to including first differences in lags and leads of the various quantity variables, in the first step, an intercept, 11-monthly binary variables, and a linear time-trend variable are included to purge the error of any seasonal effects and influence of other variable input prices.

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[11] Stock and Watson (1993) suggested that the order of lag and lead equals 2 for T = 100 and 3 for T = 300.

Although the above approach is useful to remove effects of endogeneity and to correct for the effect of unit roots, there is no guarantee the approach will correct for autocorrelation in the residuals. Therefore, the model was estimated assuming the error terms follow the first-order error correction processes:

$$\begin{aligned} \varepsilon_{jt} &= \delta_j \varepsilon_{jt-1} + \sum_{l \neq j} \delta_l \varepsilon_{lt-1} + v_{jt} \forall j \\ \varepsilon_{kt} &= \delta_k \varepsilon_{kt-1} + \sum_{m \neq j} \delta_m \varepsilon_{mt-1} + v_{kt} \forall k . \end{aligned} \tag{B.12c}$$

The stochastic specification of the RM was as follows:

$$\overline{S}_{jt} \Delta \log Y_{jt} = a_j + \sum_{k=1}^{n} c_{jk} \Delta \log P_{jt} + b_j \Delta \log X_t + u_{jt} , \tag{B.13a}$$

where u_{jt} is the error term. In estimation, the restriction of homogeneity ($\sum_k c_{jk} = 0$) is tested prior to imposition, while symmetry ($c_{jk} = c_{kj}$) is imposed a priori. We have also estimated the model assuming first-order autocorrelation in the error terms of the form:

$$u_{jt} = \rho_j u_{jt-1} + \sum_{k \neq j} \rho_k u_{kt-1} + e_{jt} \quad \forall j . \tag{B.13b}$$

Eqs. (B.12a), (B.12b), and (B.13a) are estimated as separate blocks of equations. All three sets of equations are estimated by the iterated seemingly unrelated regression (ITSUR) method, which is equivalent to maximum likelihood estimation, assuming the error terms are normally distributed. In the case of the RM, one equation needs to be deleted before estimation because of singularity of the variance-covariance matrix of the residuals due to the adding-up property. Although recouping all the parameter estimates of the underlying autoregressive process in Eq. (B.13b) is not possible, Berndt and Savin (1975) showed that the estimation results are invariant of the equation that is deleted.

For economic surplus analysis, we required that the Hessian matrix of second-order partial derivatives with respect to quantities of outputs of the profit function be positive semidefinite, the Hessian matrix of second-order partial derivatives with respect to quantities of inputs be negative semidefinites, and the Hessian matrix of the expenditure function associated with the demand functions with respect to output prices be negative semidefinite. In the empirical application, these restrictions are violated in some instances, so it is important to impose these restrictions before conducting the analysis. The approach taken in imposing semidefiniteness is the semiflexible functional form approach of Diewert and Wales (1988). In this approach, the Hessian matrix is restricted to have rank less than or equal to $K < N$, the number of second-order partial derivatives that can attain arbitrary values. As Diewert and Wales show, the semiflexible functional form is less flexible but requires fewer parameters and does not restrict its second-order parameters in any obvious restrictive manner. The advantage of the approach is that it can overcome degrees-of-freedom problems and computational problems that may arise in estimation stemming from multicollinearity or lack of identification of the underlying structural parameters.

The semiflexible functional form approach is implemented by imposing semidefiniteness in the packer relationships as follows:

(a) $\tilde{\mathbf{B}} = [b_{jl}] = \mathbf{SS}'$, where $\mathbf{B}$ is approximated by the matrix $\tilde{\mathbf{B}}$, which has rank less than the matrix $\mathbf{B}$.

(b) $\tilde{\mathbf{A}} = [a_{km}] = \mathbf{SS}'$, where $\mathbf{A}$ is approximated by the matrix $\tilde{\mathbf{A}}$, which has rank less than the matrix $\mathbf{A}$.

For the RM, the matrix $\tilde{\mathbf{C}} = [c_{jk}] = \mathbf{SS}'$ is specified to approximate the matrix $\mathbf{C}$, where $\tilde{\mathbf{C}}$ has rank less than the matrix $\mathbf{C}$. Barten and Geyskens (1975) showed that if the matrix $\mathbf{C}$ is negative semidefinite, then the demand elasticities will globally satisfy the integrability requirement of demand.

B.4 ECONOMETRIC RESULTS

The econometric estimation proceeded in a number of preliminary steps. The first step was to determine the time-series properties of the variables used in estimating the packer behavioral Eqs. (B.12a) and (B.12b). Augmented Dickey-Fuller (ADF) tests were conducted for all the quantity and price variables used in estimating the packer behavioral equations. Unit roots were indicated in all variables, with the possible exception of quantities of ribs, belly, and picnic cuts.

Equations in (B.12a) and (B.12b) without symmetry imposed were estimated by OLS, with first-order autocorrelation to check for stationarity in the error terms.[12] Using the critical values established by Engle and Granger (1987, Table II) for the Dickey-Fuller (DF) test,[13] the null hypothesis of a unit root in the error term was rejected at the 1% significance level for the loin, butt, ham, rib, and picnic price equations, and the null hypothesis of a unit root was rejected at the 10% level for the negotiated, contract, and ownership price equations.

The econometric estimates of the packer output price behavioral equations, Eq. (B.12a), are shown in Table B-3.[14] The subscripts for b_{jl} refer to loin, butt, ham, rib, belly, and picnic. The coefficient estimates associated with c_j refer to the index of hog quantities slaughtered. The pattern of effects of output on wholesale meat values is mixed and complex. In some instances (loin and picnic), there is a clear positive relationship between price and own-quantity; in other cases (ham, rib, and belly), there appears to be a negative relationship between price and own-quantity. With the exceptions of ham and ribs, there is a strong negative relationship between quantity of hogs slaughtered and wholesale values of pork. The packer price equations were also estimated subject to the restriction that the coefficients associated with the output quantity variables be positive semidefinite. The matrix $\tilde{\mathbf{B}} = \mathbf{SS}'$ only consists of one K column. Attempts to obtain estimates with more than one K were unsuccessful because of nonconvergence. The semidefinite constrained estimates are shown in Table B-4.

The results indicate that all wholesale cuts are complements, as one might expect. Furthermore, the quantity of hogs is negative and statistically significant except for the case of ham. Differences in the estimated c_j's indicate that changes in the quantities of hogs slaughtered have much different effects on marginal costs of production of different wholesale cuts.

[12] Correction for first-order autocorrelation seemed to be adequate. Estimation with up to fourth-order correction indicated little effect of autocorrelation beyond one period.

[13] Engle and Granger (1987) indicated that although the ADF tests are generally preferred to the DF tests, the latter are appropriate when we believe that the autocorrelation process is first order, as is the case here.

[14] For sake of presentation, only the parameter estimates of the b_{jl}'s and c_j's are shown.

Table B-3. Packer Output Price Equation Estimates, Symmetry Imposed

Parameter	Estimate	Standard Error	t Value	Pr > |t|
b_{11}	0.127172	0.0637	2.00	0.0473
b_{12}	0.046169	0.0611	0.76	0.4507
b_{13}	0.034437	0.0502	0.69	0.4932
b_{14}	0.023750	0.0826	0.29	0.7740
b_{15}	0.244832	0.0658	3.72	0.0003
b_{16}	0.151550	0.0412	3.68	0.0003
c_1	–0.310680	0.0641	–4.84	<0.0001
b_{22}	–0.086470	0.0916	–0.94	0.3463
b_{23}	–0.104500	0.0570	–1.83	0.0682
b_{24}	–0.274100	0.1051	–2.61	0.0098
b_{25}	0.267459	0.0764	3.50	0.0006
b_{26}	0.013975	0.0524	0.27	0.7899
c_2	–0.241950	0.0671	–3.60	0.0004
b_{33}	–0.250280	0.0585	–4.28	<0.0001
b_{34}	–0.195840	0.0827	–2.37	0.0188
b_{35}	0.112652	0.0654	1.72	0.0865
b_{36}	–0.009510	0.0423	–0.22	0.8222
c_3	0.110026	0.0583	1.89	0.0606
b_{44}	–0.641310	0.2164	–2.96	0.0034
b_{45}	0.347627	0.1132	3.07	0.0024
b_{46}	–0.047110	0.0846	–0.56	0.5780
c_4	–0.031660	0.0835	–0.38	0.7051
b_{55}	–0.243480	0.1208	–2.02	0.0452
b_{56}	0.257595	0.0560	4.60	<0.0001
c_5	–0.292420	0.0737	–3.97	0.0001
b_{66}	0.124327	0.0658	1.89	0.0603
c_6	–0.124120	0.0421	–2.95	0.0036

Table B-4. Packer Output Price Equation Estimates, Symmetry and Positive Semidefiniteness Imposed

Term	Estimate	Standard Error	t Value	Pr > |t|
b_{11}	0.174577	0.0544	3.21	0.0016
b_{12}	0.112251	0.0493	2.28	0.0238
b_{13}	0.101643	0.0406	2.50	0.0132
b_{14}	0.130789	0.0702	1.86	0.0640
b_{15}	0.177195	0.0566	3.13	0.0020
b_{16}	0.184043	0.0397	4.64	<0.0001
b_{22}	0.072177	0.0483	1.49	0.1370
b_{23}	0.065356	0.0352	1.86	0.0646
b_{24}	0.084096	0.0559	1.50	0.1339
b_{25}	0.113935	0.0522	2.18	0.0303
b_{26}	0.118338	0.0468	2.53	0.0123
b_{33}	0.059179	0.0339	1.74	0.0826
b_{34}	0.076149	0.0484	1.57	0.1169
b_{35}	0.103168	0.0448	2.30	0.0223
b_{36}	0.107155	0.0391	2.74	0.0067
b_{44}	0.097984	0.0885	1.11	0.2696
b_{45}	0.132751	0.0727	1.83	0.0694
b_{46}	0.137881	0.0704	1.96	0.0514
b_{55}	0.179852	0.0824	2.18	0.0303
b_{56}	0.186803	0.0498	3.75	0.0002
b_{66}	0.194023	0.0553	3.51	0.0005
c_1	–0.345060	0.0602	–5.73	<0.0001
c_2	–0.295260	0.0607	–4.87	<0.0001
c_3	–0.026610	0.0535	–0.50	0.6196
c_4	–0.109900	0.0766	–1.43	0.1529
c_5	–0.315450	0.0691	–4.56	<0.0001
c_6	–0.166590	0.0412	–4.05	<0.0001

The packer output constant input demand functions for hogs procured from different markets are shown in Tables B-5 and B-6.[15] For the semiflexible functional form estimates in Table B-6, two *K*s were used to approximate the matrix $\mathbf{A}$. Recall that the specification Eq. (B.12b) indicates that the a_{km}'s should be positive to obtain downward-sloping demand functions, which is the case in every instance. The results clearly indicate that all inputs are substitutes and that the quantity of pork produced and sold has a strong and positive effect on demand for hogs. Moreover, there is little difference between the results when negative semidefiniteness is imposed and when it is not imposed.

Table B-5. Packer Output Constant Inverse Input Demand Functions, Symmetry Imposed

Parameter	Estimate	Standard Error	t Value	Pr > |t|
a_{11}	0.252669	0.0503	5.03	<0.0001
a_{12}	0.195627	0.0367	5.33	<0.0001
a_{13}	0.149206	0.0514	2.90	0.0041
a_{22}	0.138016	0.0279	4.94	<0.0001
a_{23}	0.168122	0.0370	4.54	<0.0001
a_{33}	0.026425	0.0550	0.48	0.6311
d_1	0.100432	0.0400	2.51	0.0127
d_2	0.069339	0.0305	2.27	0.0242
d_3	0.078254	0.0406	1.93	0.0554

The results for the demand functions for the six wholesale pork cuts are shown in Tables B-7 and B-8. In estimation, one of the equations had to be dropped because of the adding-up restriction, so the equation for picnic cuts was dropped. As indicated above, the results are invariant to which equation is deleted.

[15] The subscripts 1, 2, and 3 refer to negotiated, contract, and owned pigs.

Table B-6. Packer Output Constant Inverse Input Demand Functions, Symmetry and Semidefiniteness Imposed

Term	Estimate	Standard Error	t Value	Pr > |t|
a_{11}	0.285041	0.0509	5.60	<0.0001
a_{12}	0.171702	0.0358	4.80	<0.0001
a_{13}	0.197988	0.0502	3.94	0.0001
a_{22}	0.121516	0.0271	4.49	<0.0001
a_{23}	0.133725	0.0350	3.82	0.0002
a_{33}	0.149085	0.0477	3.12	0.0020
d_1	0.096735	0.0398	2.43	0.0160
d_2	0.065050	0.0302	2.15	0.0324
d_3	0.080079	0.0403	1.99	0.0484

The homogeneity restriction was tested and not rejected and therefore imposed in estimation. It was unnecessary to use a reduced set of *K*s for the **S** matrix in imposing negative semidefiniteness, so the fully restricted estimates are shown in Table B-8. As the table shows, there is very little difference between the two sets of estimates, suggesting that negative semidefiniteness very nearly holds without imposing the restriction. Most of the cross-price effects are positive, and many are statistically significant, indicating substitute relationships between the various wholesale products.

Using the parameter estimates from Table B-4, Table B-9 presents the elasticities for output prices with respect to quantities of outputs and quantities of inputs.[16] Using the parameter estimates from Table B-6, Table B-10 presents the elasticities for the three hog prices with respect to quantities of outputs and quantities of inputs. For the most part, these elasticities seem reasonable. Output prices with respect to output quantities are all relatively inelastic, as one might

[16] The elasticities are evaluated at the sample means. For the input quantities (respectively, output quantities in input demand functions), the derivatives of the index with respect to components of the index can be shown to equal $\partial X_{Id} / \partial X_k = S_k^x / X_k$, where S_k^x is the cost share of the *k*th factor in total hog procurement costs.

Table B-7. Demand Functions for Wholesale Pork Cuts, Symmetry Imposed

Parameter	Estimate	Standard Error	t Value	Pr > |t|
b_{11}	–0.831170	0.1275	–6.52	<0.0001
b_{12}	0.258454	0.0708	3.65	0.0003
b_{13}	0.289427	0.0695	4.16	<0.0001
b_{14}	0.141797	0.0591	2.40	0.0174
b_{15}	0.153251	0.0591	2.59	0.0102
b_{16}	–0.011760	0.0384	–0.31	0.7596
b_{22}	–0.376610	0.0626	–6.01	<0.0001
b_{23}	0.035848	0.0462	0.78	0.4390
b_{24}	–0.023070	0.0414	–0.56	0.5778
b_{25}	0.064963	0.0392	1.66	0.0991
b_{26}	0.040413	0.0267	1.51	0.1321
b_{33}	–0.373270	0.0677	–5.51	<0.0001
b_{34}	0.026085	0.0412	0.63	0.5270
b_{35}	0.008302	0.0412	0.20	0.8403
b_{36}	0.013604	0.0261	0.52	0.6032
b_{44}	–0.141680	0.0592	–2.39	0.0177
b_{45}	0.032045	0.0371	0.86	0.3889
b_{46}	–0.035180	0.0307	–1.14	0.2537
b_{55}	–0.272970	0.0493	–5.53	<0.0001
b_{56}	0.014408	0.0245	0.59	0.5571
b_{66}	–0.021490	0.0352	–0.61	0.5420
c_1	0.586584	0.0537	10.91	<0.0001
c_2	0.138045	0.0371	3.72	0.0003
c_3	0.025510	0.0430	0.59	0.5539
c_4	0.141406	0.0270	5.24	<0.0001
c_5	0.134505	0.0312	4.31	<0.0001
c_6	–0.026050	0.0160	–1.63	0.1045

Table B-8. Demand Functions for Wholesale Pork Cuts, Symmetry and Negative Semidefiniteness Imposed

Term	Estimate	Standard Error	t Value	Pr > |t|
b_{11}	–0.831250	0.1272	–6.54	<0.0001
b_{12}	0.258599	0.0706	3.66	0.0003
b_{13}	0.289421	0.0694	4.17	<0.0001
b_{14}	0.141938	0.0590	2.41	0.0170
b_{15}	0.153425	0.0589	2.60	0.0099
b_{16}	–0.012130	0.0383	–0.32	0.7515
b_{22}	–0.376670	0.0625	–6.03	<.0001
b_{23}	0.035751	0.0461	0.78	0.4390
b_{24}	–0.023100	0.0413	–0.56	0.5762
b_{25}	0.064889	0.0391	1.66	0.0986
b_{26}	0.040537	0.0267	1.52	0.1299
b_{33}	–0.373230	0.0675	–5.53	<0.0001
b_{34}	0.025976	0.0411	0.63	0.5276
b_{35}	0.008201	0.0411	0.20	0.8419
b_{36}	0.013879	0.0261	0.53	0.5950
b_{44}	–0.141770	0.0591	–2.40	0.0174
b_{45}	0.032009	0.0370	0.86	0.3882
b_{46}	–0.035050	0.0307	–1.14	0.2542
b_{55}	–0.273110	0.0492	–5.55	<0.0001
b_{56}	0.014582	0.0244	0.60	0.5513
b_{66}	–0.021810	0.0351	–0.62	0.5349
c_1	0.586511	0.0536	10.94	<0.0001
c_2	0.138029	0.0371	3.73	0.0003
c_3	0.025546	0.0429	0.60	0.5523
c_4	0.141426	0.0269	5.25	<0.0001
c_5	0.134508	0.0311	4.32	<0.0001
c_6	–0.026020	0.0159	–1.63	0.1040

Table B-9. Elasticities of Wholesale Pork Prices with Respect to Wholesale Pork Quantities and Hog Quantities

Price / Quantity	Loin	Butt	Ham	Rib	Belly	Picnic
Loin	0.240963	0.081907	0.119929	0.020513	0.048220	0.067907
Butt	0.208991	0.071040	0.104016	0.017791	0.041822	0.058897
Ham	0.222754	0.075718	0.110866	0.018963	0.044576	0.062775
Rib	0.118273	0.040203	0.058865	0.010068	0.023668	0.033331
Belly	0.232863	0.079154	0.115897	0.019823	0.046599	0.065624
Picnic	0.496953	0.168923	0.247336	0.042305	0.099447	0.140048

Price / Quantity	Negotiated	Contract	Packer Owned
Loin	–0.21151615	–1.106380	–0.325447
Butt	–0.24413320	–1.276988	–0.375633
Ham	–0.02589864	–0.135468	–0.039849
Rib	–0.04413636	–0.230864	–0.067910
Belly	–0.18410432	–0.962995	–0.283270
Picnic	–0.19976967	–1.044936	–0.307374

Table B-10. Elasticities of Hog Prices with Respect to Wholesale Pork Quantities and Hog Quantities

Price / Quantity	Loin	Butt	Ham	Rib	Belly	Picnic
Negotiated	0.25576368	0.100375	0.137823	0.044771	0.053287	0.034957
Contract	0.03365456	0.013208	0.018135	0.005891	0.007012	0.004600
Owned	0.14666750	0.057560	0.079035	0.025674	0.030557	0.020046

Price / Quantity	Negotiated	Contract	Packer Owned
Negotiated	–0.2419967	–0.744966	–0.242651
Contract	–0.1434929	–0.518977	–0.161328
Owned	–0.1581564	–0.545909	–0.154206

expect. Also, all three inputs are net substitutes, as one would anticipate.

Table B-11a shows compensated unconditional demand elasticities for pork cuts. Unconditional demand elasticities that take into account the impact of price changes on the first-stage allocation of total expenditures between pork and other goods are required. The formula used to calculate these elasticities is Barten (1977):

$$e_{ij} = e_{ij}^{p} + e_{i}^{p} e_{pp} s_{j}^{p} \quad ,$$

where the unconditional elasticity, e_{ij}, equals the conditional elasticity, e_{ij}^{p}, plus the expenditure elasticity from the second stage for good *i*, e_{i}^{p}, multiplied by the own-price elasticity of demand for pork from the first stage, e_{pp}, all multiplied by the expenditure share of the *j*th good relative to expenditures on pork, s_{j}^{p}. These unconditional elasticities are computed at the sample means of the shares, assuming the own-price elasticity of demand for all pork is –0.29.[17] The compensated elasticities (both price and expenditure elasticities) are calculated from the parameter estimates in Table B-8. Note that with the exception of picnic cuts, the own-price elasticities are all elastic. This indicates quite high substitutability on the demand side between different cuts.

Table B-11a. Compensated Unconditional Demand Elasticities for Wholesale Pork Cuts

Quantity / Price	Loin	Butt	Ham	Rib	Belly	Picnic
Loin	–2.207947	0.567127	0.617744	0.318146	0.340639	–0.053020
Butt	1.513241	–2.392904	0.168306	–0.162192	0.384045	0.239256
Ham	1.302845	0.157238	–1.705279	0.115771	0.034436	0.061259
Rib	1.753207	–0.415594	0.237441	–2.026365	0.399380	–0.522921
Belly	1.617834	0.689938	–0.004497	0.343803	–3.252382	0.145944
Picnic	–0.162426	0.748739	0.278712	–0.619005	0.273021	–0.383587

[17] From the agricultural economics literature, the own-price elasticity of retail demand for pork is estimated to be about –0.7 (Huang, 1993). A lower-bound estimate of the wholesale demand elasticity can be obtained by multiplying the wholesale share of retail dollar by the retail demand elasticity. The average wholesale share value is estimated to be 0.41, so (.41)(–0.7) = –0.29.

Uncompensated elasticities are shown in Table B-11b. These elasticities are computed using the general Slutsky equation

$$e_{ij}^{u} = e_{ij} - s_j e_i \quad ,$$

where e_{ij}^{u} is the uncompensated unconditional elasticity between goods *i* and *j*, e_{ij} is the compensated unconditional elasticity, s_j is the share of the good in total consumer expenditures, and e_i is the unconditional expenditure elasticity of the *i*th good.[18]

Table B-11b. Uncompensated Unconditional Demand Elasticities for Wholesale Pork Cuts

Quantity / Price	Loin	Butt	Ham	Rib	Belly	Picnic
Loin	–2.215337	0.564227	0.613762	0.316852	0.339099	–0.054030
Butt	1.511502	–2.395292	0.167530	–0.163115	0.383439	0.239256
Ham	1.302523	0.157133	–1.705403	0.115690	0.034436	0.061259
Rib	1.751426	–0.417714	0.236050	–2.026365	0.399380	–0.522921
Belly	1.616139	0.688826	–0.004497	0.343803	–3.252382	0.145944
Picnic	–0.162099	0.748739	0.278712	–0.619005	0.273021	–0.383587

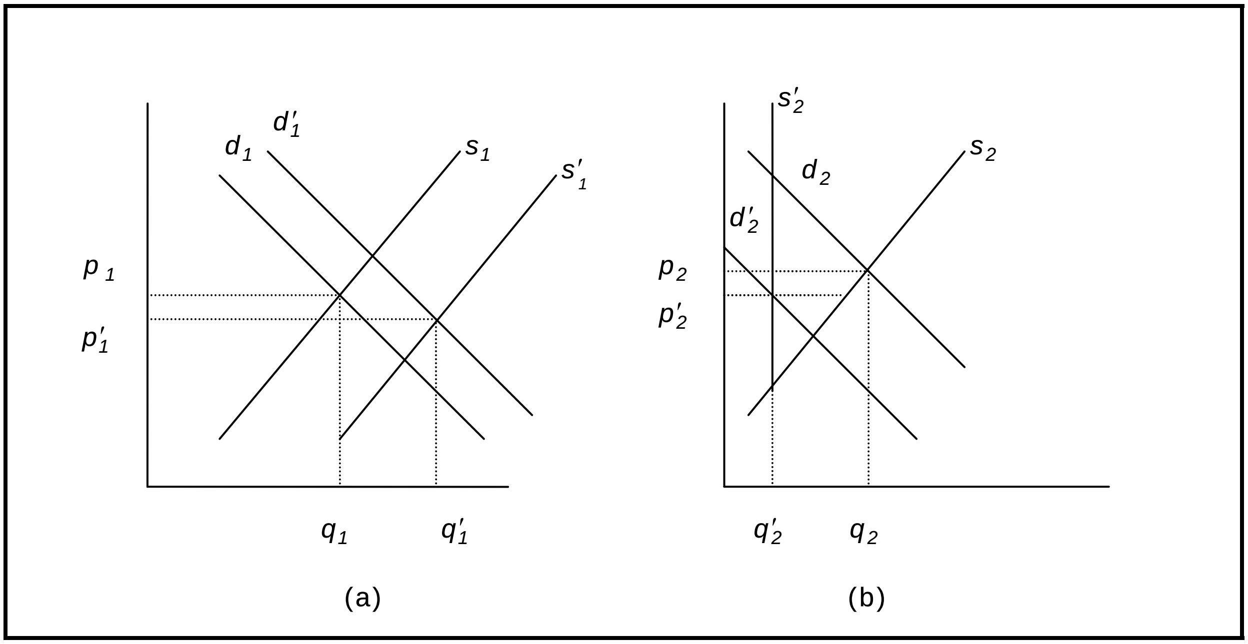
B.5 IMPACT OF CHANGES IN MARKETING ARRANGEMENTS ON THE HOG AND PORK INDUSTRIES

The estimated elasticities for packer behavior and demand will be used, together with supply elasticities for hogs, to simulate different possible restrictions on the mix of marketing arrangements. This section describes the economic processes at work that produce changes in the negotiated market and changes in the AMA supplies markets (which refers to hogs sold under contract and packer ownership in this appendix).

For the sake of presentation, assume there are two markets: (1) the negotiated or spot market and (2) the AMA supplies market. As shown in Figure B-1, a decrease in AMA supplies

[18] Edgerton (1997) showed that this elasticity can be calculated as $e_i = e_p e_i^p$, where e_p is the first-stage expenditure elasticity of pork (assumed to be 0.7 based on a study by Huang [1993]), and e_i^p is the conditional expenditure elasticity defined above.

Figure B-1. Effect on Negotiated Sales and AMA Supplies from a Restriction Reducing Availability of Hogs in AMA Supplies Market



because of restriction (panel b) causes the supply curve, s_2 , to fall and become kinked, as shown by s'_2 . Because of reduced availability of supplies from that source, packers bid up the price of hogs on the spot market causing demand to increase from d_1 to d'_1 (panel a). In response to the higher price on the spot market, producers will shift out of the AMA supplies markets and increase supply of hogs to the spot market, causing supply to increase in that market. At the same time, an increased availability of hogs from the spot market causes packers to reduce demand for hogs from AMA supplies, causing demand for hogs from AMA markets to decrease.

It is important to recognize that the supply shifts in both markets come about because of the restriction that total supply must equal the sum of supplies to both markets. Even if the supplies in both markets are independent of one another (i.e., do not depend directly on price on the other outlet), if supply in one market decreases at a given price (which is the case for AMA supplies), then supply in the other market must increase by that same amount at its original price. This is because the supply reduction is not voluntary but would come about through some type of restriction. Producers are willing to supply the original quantity at the going price in the AMA supplies market so they must be willing to supply the same quantity at that price (net of any transfer costs) in the negotiated market. Additional adjustments along the supply curves occur as the demand curves shift in response to changes in quantities marketed.

The above description assumes that (1) the different AMAs are substitutes in demand and (2) the increase in supply in the spot market exceeds the increase in demand resulting from restricting sales in the AMA supplies market. As shown below in the simulations, both of these assumptions are validated, although for other applications the assumptions may not be valid.

The economic effects of restricting sales for AMA supplies consist of effects on producers selling in the spot market, effects on producers selling in the AMA supplies markets, effects on consumers buying pork products, and effects on packers' net revenues. To compute the economic surplus effects, we needed to first develop formulas to compute equilibrium changes in the quantities and prices of the six pork cuts and the three hog AMAs. Second, given these formulas for computing changes in quantities and prices, we needed to develop formulas for calculating economic surplus effects on producers, consumers, and packers.

The model of the pork and hog industries can be expressed as an equilibrium displacement model by writing the equations describing the market in log differential form. In matrix notation, displacement in equilibrium of the nine markets can be represented as

$$\begin{aligned} \mathrm{dlog}\,\mathbf{Y} &= \mathbf{E}^{*}\mathrm{dlog}\,\mathbf{P} \\ \mathrm{dlog}\,\mathbf{P} &= \mathbf{B}^{*}\,\mathrm{dlog}\,\mathbf{Y} + \mathbf{C}^{*}\mathrm{dlog}\,\mathbf{X} \\ \mathrm{dlog}\,\mathbf{W} &= \mathbf{D}^{*}\,\mathrm{dlog}\,\mathbf{Y} - \mathbf{A}^{*}\mathrm{dlog}\,\mathbf{X} \\ \mathrm{dlog}\,\mathbf{X} &= \mathbf{F}^{*}\mathrm{dlog}\,\mathbf{W} + \mathrm{dlog}\,\mathbf{s}\,, \end{aligned} \tag{B.14}$$

where $\mathbf{Y}$ is the 6x1 vector of quantities of pork cuts, $\mathbf{P}$ is the 6x1 vector of prices of pork cuts, $\mathbf{X}$ is the 3x1 vector of quantities of hog AMAs, $\mathbf{W}$ is the 3x1 vector of prices of hog AMAs, $\mathrm{dlog}\,\mathbf{s}$ is a 3x1 vector of relative changes in supplies of hogs due to a given policy change, $\mathbf{E}^{*}$ is the 6x6 matrix of elasticities of demand for pork cuts (Table B-11b), $\mathbf{B}^{*}$ is the 6x6 matrix of elasticities of pork prices with respect to pork quantities (Table B-9), $\mathbf{C}^*$ is the 6x3 matrix of elasticities of pork prices with respect to hog quantities (Table B-9), $\mathbf{D}^*$ is the 3x6 matrix of elasticities of hog prices with respect to pork quantities (Table B-10), $-\mathbf{A}^*$ is the 3x3 matrix of flexibilities of hog prices with respect to hog quantities (Table B-10), and $\mathbf{F}^*$ is a 3x3 matrix of price elasticities of supplies of hogs. The matrix $\mathbf{F}^*$ is assumed to be diagonal. Supply elasticities are assumed to apply over two lengths of run: short run (time for adjustment of herd size to occur, approximately 1 year) and long run (assumed to represent a time period of approximately 10 years). The short-run elasticities were obtained from Zheng, Vukina, and Shin (2006). Their model, which uses Agricultural Resource Management Survey (ARMS) data to estimate supply response for cash market and production contract markets, was used to simulate elasticities by increasing price on each market and observing the outcome. Using this procedure, they obtained an estimate of the supply elasticity on the cash or negotiated market of 3.02 and an estimate for the contract market of 0.46. Throughout the analysis, we assume that the supply elasticity of hogs owned by packers is the same as that for the contract market.

The reduced-form solution to Eq. (B.14) can be characterized as follows:

$$\begin{bmatrix} \text{dlog}\,\mathbf{P} \\ \text{dlog}\,\mathbf{W} \end{bmatrix} = \begin{bmatrix} \mathbf{I}_J - \mathbf{B}^*\mathbf{E}^* & \mathbf{0} \\ -\mathbf{D}^*\mathbf{E}^* & \mathbf{I_K} \end{bmatrix}^{-1} \begin{bmatrix} \mathbf{C}^* \\ \mathbf{A}^* \end{bmatrix} \text{dlog}\,\mathbf{X} = \begin{bmatrix} \boldsymbol{\pi_p} \\ \boldsymbol{\pi_w} \end{bmatrix} \text{dlog}\,\mathbf{X} \quad \text{(B.15)}$$

and

$$\text{dlog}\,\mathbf{X} = \mathbf{F}^*\ \text{dlog}\,\mathbf{W} + \text{dlog}\,\mathbf{s}\ . \qquad \text{(B.16)}$$

The solution for the inverse industry derived demand functions is obtained from Eq. (B.15) as

$$\text{dlog}\,\mathbf{W} = \boldsymbol{\pi_w}\ \text{dlog}\,\mathbf{X}\ . \qquad \text{(B.17)}$$

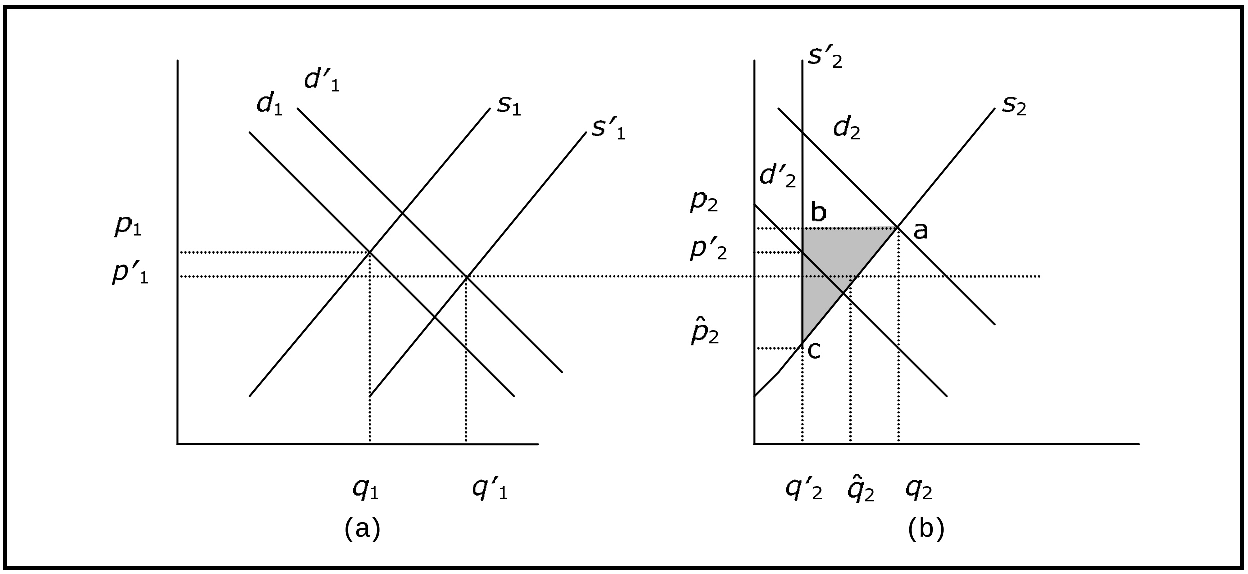
Substituting the input supply functions from Eq. (B.16) into Eq. (B.17) yields the relative changes in input prices from relative shifts in the input supply functions:

$$\text{dlog}\,\mathbf{W} = (\mathbf{I}_k - \boldsymbol{\pi_w}\mathbf{F}^*)^{-1}\boldsymbol{\pi_w}\ \text{dlog}\,\mathbf{s}\ . \qquad \text{(B.18)}$$

The solution for relative changes in input quantities is obtained by substituting Eq. (B.18) into Eq. (B.17). Given the solutions to relative changes in input quantities, the first set of solutions in Eq. (B.15), $\text{dlog}\,\mathbf{P} = \boldsymbol{\pi}_p\, \text{dlog}\,\mathbf{X}$, can be used to estimate relative changes in the wholesale prices of pork. Finally, the demand functions, $\text{dlog}\,\mathbf{Y} = \mathbf{E}^*\, \text{dlog}\,\mathbf{P}$, can be used to calculate relative changes in equilibrium quantities of pork.

Economic surplus effects from changes in the AMAs can be calculated as follows. For producers, the effects on producers selling on the spot market consist of the losses sustained from the reduced price. In Figure B-2, losses to these producers make up the area above the supply curve s_1 between prices p_1 and p_1'. For producers under contract, their losses are represented by the two areas $(p_2' - p_2)q_2'$ and the area of the triangle abc. This loss, however, is offset somewhat by the gain they receive by selling the quantity $\hat{q}_2 - q_2'$ they would wish to sell in the spot market at price p_1'.

Figure B-2. Economic Effects on Producers from a Restriction Reducing Availability of Hogs in AMA Supplies Market



The formula for changes in producer's surplus in terms of the notation of the model is as follows:[19]

[19] The values for $\hat{W}_2$ and $\hat{X}_2$ are estimated as
$\hat{W}_2 = W_2[1 + (\Delta X_2 / X_2)(1/\varepsilon_2)]$ and $\hat{X}_2 = X_2 + \varepsilon_2(W_1'' - W_2)(X_2 / W_2)$.

$$\Delta PS = \Delta W_1 X_1 + (\varepsilon_1 / 2)(X_1 / W_1)(W_1' - W_1)^2 + \Delta W_2 X_2' + (1/2)(\hat{W}_2 - W_2)(X_2 - X_2') + (1/2)(W_1' - \hat{W}_2)(\hat{X}_2 - X_2') \ . \tag{B.19a}$$

Change in consumer's surplus is evaluated using the sequential method developed by Just, Hueth, and Schmitz (1982):

$$\Delta CS = -\sum_{j=1}^{n} \int_{P_j}^{P_j'} Y_j [\hat{P}_j (P_j), U^0] dP_j \ , \tag{B.19b}$$

where $Y_j(\bullet)$ is the Hicksian demand function for the *j*th pork product. The notation $\hat{P}_j(P_j)$ indicates that the integration is sequential, with the Hicksian demand function conditional on the previous price change. For the present application, we assume that the areas above the demand curves between the prices can be approximated by the sum of rectangles and triangles. For the first good, the Hicksian demand level is conditioned on initial prices of the *n–1* other goods; for the second good, the Hicksian demand is conditioned on the new price for good 1 and *n–2* prices for the other goods; and for the *k*th good, the Hicksian demand is conditioned on the new prices for the *k–1* goods already evaluated plus the *n–k* goods not evaluated. The elasticities should be Hicksian elasticities, which are shown in Table B-11a. Although the Marshallian elasticities (Table B-11b) are used to compute the new equilibrium quantities and prices, the Hicksian elasticities are used for the economic surplus analysis.[20]

Changes in processor's net revenue can be calculated as follows:[21]

$$\begin{aligned} \Delta NetRev &= 1/2(\boldsymbol{Y}_{\boldsymbol{new}}' \boldsymbol{B} \boldsymbol{Y}_{\boldsymbol{new}} + \boldsymbol{X}_{\boldsymbol{new}}' \boldsymbol{A} \boldsymbol{X}_{\boldsymbol{new}} \\ &- \boldsymbol{Y}_{\boldsymbol{old}}' \boldsymbol{B} \boldsymbol{Y}_{\boldsymbol{old}} - \boldsymbol{X}_{\boldsymbol{old}}' \boldsymbol{A} \boldsymbol{X}_{\boldsymbol{old}}) + \Delta W_3 X_{3new} \\ &+ (1/2)(\hat{W}_3 - W_{3old})(X_3 - X_{3new}) \\ &+ (1/2)(W_{1new} - \hat{W}_3)(\hat{X}_3 - X_3') \end{aligned} \ , \tag{B.19c}$$

where the subscripts "new" and "old" refer to the new equilibrium quantities and original equilibrium quantities,

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[20] As a practical matter, it would not make that much difference if the uncompensated elasticities were used because of the small income effects (Tables B-11a and B-11b).

[21] The formulas used to compute $\hat{W}_3$ and $\hat{X}_3$ are the same as those shown in footnote 19, with the obvious change in notation from subscript 2 to subscript 3.

respectively. The first part of the formula is obtained by substituting the f.o.c. back into the processor's (quadratic) profit function and noting that the optimal profit function reduces simply to $1/2(\boldsymbol{Y'BY} + \boldsymbol{X'AX})$.[22] The last part of the formula is the economic surplus effect from forcing packer owned producers to sell hogs on the spot market.

Table B-12 presents the reduced-form, inverse industry derived demand flexibilities for the alternative sources of hog procurement. Consistent with the output constant flexibilities (Table B-10), the total effects show strong substitution between the different AMAs and the spot market. This pattern of substitution is consistent with the commonly observed phenomena that increased quantities or shares of contract and packer-owned hogs have a depressing effect on the spot price.

Table B-12. Reduced-Form, Inverse Industry Derived Demand Flexibilities for Hogs from Alternative Market Sources

Price / Quantity	Negotiated	Contract	Packer Owned
Negotiated	–0.26698155	–0.875654	–0.281093
Contract	–0.14678056	–0.536174	–0.166386
Packer owned	–0.17248395	–0.620852	–0.176251

We performed three types of simulations:

- (a) reducing both contract and packer-owned hogs by 25%
- (b) limiting the spot/cash market to 25%
- (c) banning packer-owned hogs.

The matrices of supply shifters in the three cases become

[22] To see this, note that in matrix notation the profit equation can be written $\Pi = \boldsymbol{Y'P} - \boldsymbol{X'W} - \boldsymbol{Y'b} - 0.5\boldsymbol{Y'BY} - \boldsymbol{X'a} - 0.5\boldsymbol{X'AX} - \boldsymbol{Y'CX}_{FI} + \boldsymbol{X'DY}_{FI}$.

The first-order conditions for profit maximization are $\begin{matrix} \boldsymbol{P} = \boldsymbol{b} + \boldsymbol{BY} + \boldsymbol{CX}_{FI} \\ \boldsymbol{W} = -\boldsymbol{a} - \boldsymbol{AX} + \boldsymbol{DY}_{FI} \end{matrix}$, where the intercept vectors $\boldsymbol{a}, \boldsymbol{b}$ represent the combination of market power and cost effects. Substituting the first-order conditions into the profit equation and rearranging terms leads to the expression in the text for optimal profit.

(a)

$$\Delta \log \boldsymbol{s} \cong \begin{bmatrix} -(k_2/k_1)(\Delta X_2/X_2)-(k_3/k_1)(\Delta X_3/X_3) \\ -0.25 \\ -0.25 \end{bmatrix} \cong$$

$$\begin{bmatrix} -(0.6732491/0.128711)(-0.25)-(0.1980399/0.128711)(-0.25) \\ -0.25 \\ -0.25 \end{bmatrix}$$

(b)

$$\Delta \log \boldsymbol{s} \cong \begin{bmatrix} \Delta X_1 / X_1 \\ -(k_2 / k_1)(\Delta X_2 / X_2) \\ -(k_3 / k_1)(\Delta X_3 / X_3) \end{bmatrix} \cong$$

$$\begin{bmatrix} (0.25/0.128711)-1 \\ -(1/2)[(0.25/0.128711)-1] \\ -(1/2)[(0.25/0.128711)-1] \end{bmatrix}$$

(c)

$$\Delta \log \boldsymbol{s} \cong \begin{bmatrix} -(k_3/k_1)(\Delta X_3/X_3) \\ 0 \\ -1.00 \end{bmatrix} \cong$$

$$\begin{bmatrix} -(0.1980399/0.128711)(-1.0) \\ 0 \\ -1.0 \end{bmatrix}.$$

Scenario (a)

Table B-13 presents the impact of restricting both contract and packer-owned hogs by 25% on quantities and prices of hogs and pork.

Table B-14 shows the changes in consumer's surplus, changes in processor's net revenue, and changes in producer's surplus from policy Scenario (a).

Scenario (b)

Table B-15 shows the impact of restricting both contract and packer-owned hogs on quantities and prices of hogs and pork to increase the spot market share to 25%.

Table B-16 provides the changes in consumer's surplus, changes in processor's net revenue, and changes in producer's surplus from policy Scenario (b).

Table B-13. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (a)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	5.071995	Y1	–6.254235
Butt	P2	6.047142	Y2	–4.321752
Ham	P3	0.129534	Y3	7.824395
Rib	P4	0.811994	Y4	4.340150
Belly	P5	4.280122	Y5	–0.690170
Picnic	P6	4.038218	Y6	2.858603
Negotiated	W1	–8.993384	X1	142.073600
Contract	W2	–3.287139	X2	–25
Packer owned	W3	–4.566955	X3	–25

Table B-14. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Policy Scenario (a)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–3.918210
Changes in processor's net revenue (% of total revenue of pork)	3.220613
Changes in producer's surplus (% of total revenue of hog production)	–18.498550

Table B-15. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (b)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	2.824217	Y1	–3.482518
Butt	P2	3.367203	Y2	–2.406462
Ham	P3	0.072128	Y3	4.356823
Rib	P4	0.452139	Y4	2.416707
Belly	P5	2.383281	Y5	–0.384305
Picnic	P6	2.248583	Y6	1.591743
Negotiated	W1	–5.007746	X1	79.110200
Contract	W2	–1.830363	X2	–13.920640
Packer owned	W3	–2.542997	X3	–13.920640

Table B-16. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Policy Scenario (b)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–2.131444
Changes in processor's net revenue (% of total revenue of pork)	1.711562
Changes in producer's surplus (% of total revenue of hog production)	–8.569028

Table B-18 shows the changes in consumer's surplus, changes in processor's net revenue, and changes in producer's surplus from policy Scenario (c).

Scenario (c)

Table B-17 provides the impact of banning packer-owned hogs on quantities and prices of hogs and pork.

Table B-17. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (c)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	4.844295	Y1	–5.902172
Butt	P2	5.770456	Y2	–4.082730
Ham	P3	0.137115	Y3	7.453754
Rib	P4	0.781763	Y4	4.149452
Belly	P5	4.090397	Y5	–0.650994
Picnic	P6	3.877224	Y6	2.717540
Negotiated	W1	–6.643450	X1	133.800800
Contract	W2	–2.407050	X2	–1.107242
Packer owned	W3	–4.765950	X3	–100

B.5.1 Long-Run Effects of Restricting AMAs

Effects on prices, quantities, and economic surplus measures are also calculated for a 10-year adjustment period. These long-run estimates show more of the effects passed on to consumers.

Table B-18. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Policy Scenario (c)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–3.737820
Changes in processor's net revenue (% of total revenue of pork)	0.704409
Changes in producer's surplus (% of total revenue of hog production)	–11.778780

Attachment 4 in this appendix develops the long-run supply elasticities for the three markets, which are 7.8, 2.4, and 2.4 for the spot, contract, and packer owned markets, respectively. The effects on prices; quantities; and surplus of consumers, processors, and producers using the disaggregated equilibrium displacement model are indicated below.

Scenario (a)

Table B-19 shows the long-run (10-year adjustment period) impact of restricting both contract and packer-owned hogs by 25% on quantities and prices of hogs and pork.

Table B-19. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (a) (10-year adjustment period)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	7.671774	Y1	–9.459999
Butt	P2	9.146756	Y2	–6.536973
Ham	P3	0.195929	Y3	11.834980
Rib	P4	1.228201	Y4	6.564803
Belly	P5	6.474005	Y5	–1.043934
Picnic	P6	6.108108	Y6	4.323851
Negotiated	W1	–5.266870	X1	128.152000
Contract	W2	–1.242450	X2	–25
Packer owned	W3	–2.160140	X3	–25

Table B-20 presents the long-run changes in consumer's surplus, changes in processor's net revenue, and changes in producer's surplus from policy Scenario (a).

Scenario (b)

Table B-21 shows the long-run impact of restricting both contract and packer-owned hogs on quantities and prices of hogs and pork to increase the spot market share to 25%.

Table B-20. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Policy Scenario (a) (10-Year Adjustment Period)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–6.084669
Changes in processor's net revenue (% of total revenue of pork)	1.128958
Changes in producer's surplus (% of total revenue of hog production)	–10.350590

Table B-21. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (b) (10-Year Adjustment Period)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	4.271840	Y1	–5.267569
Butt	P2	5.093148	Y2	–3.639954
Ham	P3	0.109099	Y3	6.590022
Rib	P4	0.683894	Y4	3.655450
Belly	P5	3.604892	Y5	–0.581289
Picnic	P6	3.401151	Y6	2.407631
Negotiated	W1	–2.932727	X1	71.358330
Contract	W2	–0.691827	X2	–13.920640
Packer owned	W3	–1.202820	X3	–13.920640

Table B-22 provides the long-run changes in consumer's surplus, changes in processor's net revenue, and changes in producer's surplus from policy Scenario (b).

Scenario (c)

Table B-23 shows the long-run impact of banning packer-owned hogs on quantities and prices of hogs and pork.

Table B-22. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Policy Scenario (b) (10-Year Adjustment Period)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–3.272983
Changes in processor's net revenue (% of total revenue of pork)	0.594490
Changes in producer's surplus (% of total revenue of hog production)	–5.347453

Table B-23. Percentage Changes in Wholesale Pork Prices and Hog Prices from Scenario (c) (10-Year Adjustment Period)

Variable	Percentage Changes in Prices		Percentage Changes in Quantities	
Loin	P1	7.164770	Y1	–8.729382
Butt	P2	8.534572	Y2	–6.038406
Ham	P3	0.202795	Y3	11.024190
Rib	P4	1.156237	Y4	6.137088
Belly	P5	6.049745	Y5	–0.962828
Picnic	P6	5.734460	Y6	4.019274
Negotiated	W1	–3.696744	X1	125.029400
Contract	W2	–0.749186	X2	–1.798047
Packer owned	W3	–2.824136	X3	–100

Table B-24 presents the changes in consumer's surplus, changes in processor's net revenue, and changes in producer's surplus from policy Scenario (c).

Table B-24. Effects on Consumer's Surplus, Processor's Net Revenue, and Producer's Surplus from Policy Scenario (c) (10-Year Adjustment Period)

Effect	Percentage Changes
Changes in consumer's surplus (% of total revenue of pork)	–5.660309
Changes in processor's net revenue (% of total revenue of pork)	–0.829551
Changes in producer's surplus (% of total revenue of hog production)	–6.155498

Attachment 1: Specification of Derived Demand for Pork Cuts

The theory of derived demand allows us to develop estimated demand relationships for pork cuts at the wholesale level that can be used to conduct economic surplus analysis much in the same way as the theory of consumer demand. Let Y_r, P_r, and E_r denote vectors of retail quantities, retail prices, and retail expenditures on pork. The system of consumer demand relationships can be expressed as follows:

$$Y_r = D_r(P_r, E_r) \quad . \tag{1}$$

The aggregate relationships between retail and wholesale prices (i.e., the inverse retail supply relations) can be expressed as follows:

$$P_r = S_r(P_w, C_r, Y_r) \quad , \tag{2}$$

where P_w is the vector of wholesale prices, and C_r is the vector of exogenous supply shifters (e.g., wage rates, energy prices). Input demand functions for the wholesale pork cuts by retailers are

$$Y_w = D_w(P_w, P_r, C_r) \quad . \tag{3}$$

The system of derived demand functions is obtained by solving the system of equations (1) and (2) for retail prices as a function of wholesale prices, exogenous supply shifters, and retail expenditures on pork,

$$P_r = P_r(P_w, C_r, E_r) \quad , \tag{4}$$

and then substituting the retail price functions from Eq. (4) into the wholesale input demand functions in Eq. (3):

$$Y_w = D_w[P_w, P_r(P_w, C_r, E_r), C_r] = \overline{D}_w(P_w, C_r, E_r) \quad . \tag{5}$$

Heiner (1982, 1984) and Braulke (1984) showed that these demand functions will possess the usual properties of symmetry and homogeneity (among all input prices) if the consumer demand functions are symmetric functions. This will not be true in general, as pointed out by Chavas and Cox (1997); however, if the retail demand functions are Hicksian demand functions, then these functions will be symmetric.

Another issue concerns the use of wholesale expenditure rather than retail expenditure as an explanatory variable. Note that real retail expenditures in log differential form can be written as

$$d \log \overline{E}_r = d \log E_r - \sum s_r d \log P_r \quad . \tag{6}$$

Likewise, real wholesale expenditures in log differential form is written as

$$d \log \overline{E}_w = d \log E_w - \sum s_w d \log P_w \quad . \tag{7}$$

The two will be equal if

$$\sum s_r d \log Y_r = \sum s_w d \log Y_w \quad . \tag{8}$$

In the somewhat plausible case where $d \log Y_r = d \log Y_w =$ d log Y for each pork cut, Eq. (8) reduces to

$$\sum (s_r - s_w) d \log Y = 0 \quad . \tag{9}$$

Thus, the relative change in real retail pork expenditures, Eq. (6), will equal the relative change in real wholesale pork expenditure, Eq. (7), if and only if the retail expenditure share of each cut equals its wholesale expenditure share. On the face of it, this seems entirely plausible, so it is imminently reasonable to reformulate the system of derived demand functions as follows:

$$Y_w = \overline{D}_w (P_w, C_r, \overline{E}_w) \quad . \tag{10}$$

This set of derived demand functions should be symmetric and homogenous of degree zero in wholesale pork prices and other input prices.

Attachment 2: Sources of Changes in Processing Costs

Using monthly farm–wholesale price spread for pork published by USDA over the time period that MPR was in effect, we estimated a relationship for the farm–wholesale price spread. The purpose of the exercise was to measure the effect of quantity of pork produced, effect of AMA supplies, and effect of market power on the price spread. In theory, the price spread between the farm and wholesale levels should reflect the marginal cost of producing wholesale pork. However, the price spread can also reflect market power and changes in market power as the proportion of hogs under contract and/or owned by companies increases (Azzam, 1998).

Our model follows the framework developed by Schroeter (1988). If the firm can exercise market power in both the output market (wholesale pork) and the market for the agricultural raw material input (slaughter hogs), then marginal revenue from producing another pound of pork can be expressed as

$$MR = P(1+\theta) \ ,$$

where P is wholesale price and θ / P is the marginal effect of the quantity produced on the pork price, which reflects the degree of market power in the output market. The marginal cost of procuring another pound of pork is $W_1(1+\phi)$, where W_1 is the hog price (per-unit wholesale quantity [i.e., carcass value]) and ϕ / W_1 is the marginal effect of quantity procured on the hog price, which reflects the degree of market power in the input market. The marginal cost of producing pork, consisting of the sum of procurement and production costs, equals

$$W_1(1+\phi) + \frac{\partial C}{\partial Y} \ ,$$

where $\frac{\partial C}{\partial Y}$ is the marginal production cost. Therefore, the general form of the price equation to estimate is[23]

[23] The assumption is made that there is a fixed transformation between the farm and wholesale levels. Other studies (Wohlgenant, 2001) have shown that this assumption will lead to overestimation of the degree of market power if there are variable, rather than fixed, proportions.

$$P(1+\theta) = W_1(1+\phi) + \frac{\partial C}{\partial Y} \quad . \tag{1}$$

Solving for output price and dividing by input price yields the expression

$$\frac{P}{W_1} = \frac{(1+\phi)}{(1+\theta)} + W_1^{-1}\frac{1}{(1+\theta)}\frac{\partial C}{\partial Y} \quad . \tag{2}$$

We assume the cost function is quadratic with the following form:[24]

$$C = F + W_1^{-1}(\boldsymbol{w'Aw})Y + (\boldsymbol{a'w})Y^2 \quad , \tag{3}$$

where F is fixed costs and w is the vector of processing input prices (e.g., labor, energy). The two most important processing inputs are labor and energy and time-series data on a monthly basis are readily available for these inputs. Therefore, these two input prices are used to specify production costs so Eq. (3) can be written as

$$C = F + W_1^{-1}(a_{22}W_2^2 + a_{33}W_3^2 + 2a_{23}W_2W_3)Y + (a_2W_2 + a_3W_3)Y^2 \quad . \tag{4}$$

Because of multicollinearity, we chose to aggregate labor (W_2) and energy (W_3) into one index using the Fisher Ideal index. Diewert (1976) has shown that this index is exact for a quadratic function, which is the case here, so little is lost by using this specification. Therefore, the cost function with an aggregate input price index is

$$C = F + W_1^{-1}(\alpha W_{FI}^2)Y + \beta W_{FI}Y^2 \quad , \tag{5}$$

where the subscript "*FI*" refers to the Fisher Ideal index. In addition to the above modifications, we also assume that both parameters in the cost function depend on the proportion of hogs procured through AMA supplies, *amashare*. Thus, the cost function is represented as

$$C = F + W_1^{-1}(\alpha_0 + \alpha_1 amashare)W_{FI}^2 Y + (\beta_0 + \beta_1 amashare)W_{FI}Y^2 \quad . \tag{6}$$

[24] This specification is different than other specifications in that all fixed and variable costs have been separated. Because the firm will not incur variable costs when output is zero, functions of variable input prices must interact with output, as indicated in this specification.

Finally, to account for the fact that market power, particularly in the input market, can depend on the proportion of hogs either under contract or packer owned, we make the parameter ϕ a function of $amashare$. If the relationship is linear, $\phi = \phi_0 + \phi_1 amashare$, Eq. (2) can be expressed as

$$\frac{P}{W_1} = \frac{(1+\phi_0 + \phi_1 amashare)}{(1+\theta)} + W_1^{-1}\frac{1}{(1+\theta)}\frac{\partial C}{\partial Y} \quad .$$

Differentiating total costs with respect to output and substituting for marginal cost yields

$$\frac{P}{W_1} = \frac{(1+\phi_0 + \phi_1 amashare)}{(1+\theta)} + \frac{1}{(1+\theta)}(\alpha_0 + \alpha_1 amashare)\left(\frac{W_{FI}}{W_1}\right)^2 + (\beta_0 + \beta_1 amashare)\left(\frac{W_{FI}}{W_1}\right)Y$$

or more simply

$$\begin{aligned}\left(\frac{P}{W_1}\right)_t &= b_0 + b_1 amashare_t + (c_0 + c_1 amashare_t)\left(\frac{W_{FIt}}{W_{1t}}\right)^2 \\ &+ (d_0 + d_1 amashare_t)\left(\frac{W_{FIt}}{W_{1t}}\right)Y_t + u_t \quad ,\end{aligned} \tag{7}$$

where u_t is the error term.

Eq. (7) can be used to estimate separately the influence of market power and production costs on the farm–wholesale price spread. The markup/markdown value is estimated as the sum of the first two terms in Eq. (7). If markup power is present, then we would expect these two terms (evaluated at some data point, for example, the sample mean) to be significantly different from one and larger than one numerically. The coefficients associated with output in the marginal production cost portion of the equation (the last set of terms) indicate whether there are increasing, constant, or decreasing returns to scale. Also, it is possible to differentiate between the economies/diseconomies of scale depending on the source of input purchases. Finally, the equation allows us to estimate the net effect of AMA supplies on market power and marginal production costs.

The model, Eq. (7), was estimated with monthly data from August 2001 through September 2005, the period in which MPR was in effect. Data for wholesale and farm prices are USDA price spread data for pork, output is the quantity of pork produced in each month in the United States, and W_{2t} is an index of processing costs consisting of costs of slaughtering and energy prices.

In estimating Eq. (7) with time-series data, it is important to note that unit roots are present in the series, so it is important to include leads and lags of the right-hand variables in estimation (Phillips and Loretan, 1991). First-order differences on leads and lags were included in the model, but only first-order differences (as a group) were found significant and were retained. The estimated equation is shown in Table 1.[25] As indicated, AMA supplies have a positive impact on market power but a negative impact on marginal costs. At the sample mean, a one-unit change in output causes marginal costs to increase by only 7.36302×10^{-5}(elasticity at sample means equals 0.04). This suggests that the average firm in the industry is operating near constant returns to scale. The average markup/markdown is 1.108104 (coefficient on *amashare* multiplied by the mean value of *amashare*). The standard error of this coefficient estimate is 0.035196. For the null hypothesis of no market power (coefficient equal to one) the t-value is 3.07146. Therefore, we strongly reject price-taking behavior, although the degree of market power is modest.

The estimated covariances of the parameter estimates were used with the parameter estimates of the price spread equation to estimate the effect of AMA supplies on market power, AMA supplies on marginal costs, and net effect on the price ratio. In terms of elasticities, a 1% increase in AMA supplies leads to a 0.734617% increase in market power, with a standard error of 0.020228, holding marginal costs constant. A 1% increase in AMA supplies leads to a –4.99137% change in marginal costs, with a standard error of –1.67052, holding the degree of market power constant. The net effect of market power and efficiency gains from increased AMA supplies is therefore –1.47107%, with a standard error of –0.4021 for each 1% increase in AMA supplies. Thus, the benefits from increased AMA supplies outweigh increases in market power through decreased costs in procuring and processing pork.

[25] The intercept was also found to be insignificant and was deleted from the model.

Table 1. Estimates of Farm–Wholesale Price Spread for Pork, August 2001–September 2005

Variable	Wholesale–Farm Price Ratio
$amashare_t$	1.278235 (0.0406)
$\left(\frac{W_{FIt}}{W_{1t}}\right)^2$	–21,806.8 (14,888.8)
$amashare_t \left(\frac{W_{FIt}}{W_{1t}}\right)^2$	27,004.8 (17,138.9)
$\left(\frac{W_{FIt}}{W_{1t}}\right)Y_t$	0.348274 (0.1153)
$amashare_t \left(\frac{W_{FIt}}{W_{1t}}\right)Y_t$	–0.39560 (0.1324)
$\Delta\left(\frac{W_{FIt}}{W_{1t}}\right)^2$	19,220.84 (8,887.1)
$\Delta\left[amashare_t \left(\frac{W_{FIt}}{W_{1t}}\right)^2\right]$	–22,217.7 (10,266.9)
$\Delta\left(\frac{W_{FIt}}{W_{1t}}\right)Y_t$	–0.23965 (–0.0708)
$\Delta\left[amashare_t \left(\frac{W_{FIt}}{W_{1t}}\right)^2 Y_t\right]$	0.273775 (0.0814)
R^2	0.96680
$\hat{p}$	0.622802 (0.1345)

Note: Values in parentheses are estimated standard error; $\hat{\rho}$ is the estimate of the first-order autocorrelation parameter.

Attachment 3: Monthly Demand for Pork and Market-Level Effects from Restricting AMA Supplies

We also estimated monthly wholesale demand for pork. The model estimated is a linear specification of per capita pork consumption as the dependent variable; independent variables are the deflated wholesale price of pork, deflated retail price of beef, deflated retail price of poultry (weighted average of chicken and turkey prices), and per capita deflated disposable personal income. In addition, first differences in lags and leads of the right-hand side variables are included in the model to account for the effect of unit roots in prices and income variables.[26] These results are shown in Table 1. These results are reasonable and have the expected signs except for the income variable, although it is statistically insignificant. The own-price elasticity of demand at the wholesale level is calculated to be –0.38, which is in the range of estimates obtained from other studies.

The estimated parameters of the price spread and the demand for pork were used to assess the validity of the economic surplus calculations from the 17-equation model. For this purpose, we also need the elasticity of supply for hogs. We used the weighted average of short-run elasticities for the spot and contract markets of 3.02 and 0.46, respectively, to obtain an aggregate short-run estimate of 0.79. The comparative statics formula for the total elasticity of farm price with respect to a 1% change in AMA supplies is

$$E_{famash} = \frac{\eta e_{wamash}}{(\varepsilon - e\eta)} ,$$

where η is the own-price elasticity of wholesale demand for pork (η = –0.38), e_{wamash} is the elasticity of wholesale price with respect to AMA supplies (e_{wamash} = –1.47), ε is the elasticity of farm supply (ε = 0.79), and e is the elasticity of price transmission of wholesale price with respect to farm price (e = 0.86). Using the above formula, the effect of a 25%

[26] First differences in leads were included to account for simultaneity, which appears to be present. There was no indication that seasonality was important for this sample period. The F-test for the null hypothesis that the monthly binary variables equals zero was 1.79. The critical value for the F-statistic at the 5% level is 2.22.

Table 1. Estimates of Monthly Wholesale Demand for Pork

Variable	Per Capita Pork Consumption
Constant	–2.65727 (5.6319)
Deflated wholesale pork price	–0.03523 (0.0151)
Deflated retail beef price	0.01416 (0.00841)
Deflated retail poultry price	0.111327 (0.0436)
Deflated per capita disposable personal income	–0.15254 (0.4373)
First-difference deflated wholesale pork price	–0.04335 (0.0225)
First-difference deflated retail beef price	–0.01386 (0.0137)
First-difference deflated retail poultry price	–0.08263 (0.0507)
First-difference deflated per capita disposable personal income	–0.08978 (0.4142)
First-difference (lead) deflated wholesale pork price	–0.46848 (0.0546)
First-difference (lead) deflated retail beef price	0.030095 (0.0125)
First-difference (lead) deflated retail poultry price	–0.02901 (0.0525)
First-difference (lead) deflated per capita disposable personal income	0.030956 (0.4147)
R^2	0.7787
D.W.	2.0216

D.W. is the Durbin-Watson statistic.

reduction in AMA supplies is the value of the formula multiplied by –25 and equals –12.6%. That is, a 25% reduction in all contracts and packer-owned hogs is predicted to decrease the spot price of hogs by 12.5%. How does this prediction compare with the disaggregated model? For the disaggregated model, this simulation predicts the spot price would decline 9%, which is close to the prediction from the aggregate model. Thus, it is reasonable to conclude that the disaggregate model does indeed produce reasonable results, if in fact we accept the aggregate model as a reasonable description of the pork industry.

Attachment 4: Long-Run Impacts of Changes in AMAs

One important way in which the long-run analysis differs from the short-run analysis is that producers would be free to move from one supply source to another. Economic theory would predict that, aside from transaction and transfer costs, prices on the different outlets should be equal. Thus, we might consider the average prices on the three outlets as reflecting in some sense intrinsic differences between returns on the three markets. These restrictions and an estimate of aggregate supply elasticity for the long run (i.e., 10-year adjustment period) would characterize the supply structure of the model and could be used with the demand-side parameters from the packer model and wholesale demand structure for pork to estimate the long-run economic surplus effects for the three scenarios.

However, in a regulatory environment, producers are not free to move from one market to the other. In particular, while producers can sell in the spot market, they would be forced to reduce supplies in the other markets. Thus, we would not necessarily expect proportionate changes in prices on the three market outlets, even in the long run.

An estimate of supply response of hogs over a 10-year period was obtained from an econometric model of the hog industry using state-level annual data from USDA, ARMS from 1994 to 2001. By pooling cross-section time-series data, we were able to enlarge the sample and account for heterogeneity in production across the country. The particular model estimated was a dynamic model. The structural model gives end-of-the-year inventory of farrowing sows as a linear function of beginning-of-the-year inventory and the present discounted value of quasi rents from farrowing sows. Market hog production is then determined by multiplying the number of sows farrowing by the number of pigs per litter and average weight per market hog. Empirically, only sows farrowing was found to be price responsive so that the percentage change in number of sows farrowing over time in response to a price change is equivalent to the percentage change in quantity of market hogs sold in response to a price change. The model estimated had the general form (Wohlgenant, 2005),

$$b_{t+1} = \lambda_1 b_t + \lambda_1 \beta\omega \sum_{j=0}^{\infty} (\lambda_1 \beta)^j Em_{t+1+j} \quad , \tag{1}$$

where b_{t+1} is the end-of-the-year inventory of farrowing sows, Em_{t+1+j} is expected quasi rents (i.e., hog price minus feed costs per pound market hog) in year $t+1+j$, and the other terms in the equation are parameters to estimate. The expected quasi rents were related to observed prices of hogs, corn, and soybean meal by assuming producers form quasirational expectations. This modeling approach says that producers look to the past history of the price variable in question and form forecasts based on the best univariate time-series model. Nerlove and Bessler (2001) argue that this model of expectations is preferable to the alternatives available in the literature. Using this approach, we found that the optimal price predictors for both hog prices and feed prices (weighted average of corn and soybean meal prices) indicated that producers only need to look at last year's price when forming price expectations. With these specifications for price expectations and the supply model indicated above, we identified and estimated the parameters of the supply model. The estimated supply model is

$$b_{it+1} = const + 0.7735 b_{it} + 1.035 \sum_{j=0}^{\infty} (0.7367)^j Ep_{it+1+j} \quad , \tag{2}$$

where the subscript "i" refers to a particular state. The advantage of this model is that expectations are separated from adjustment costs so that supply elasticities can be calculated for different scenarios for how producers respond to interventions. In the present application, it seems reasonable that producers would view restrictions on AMA supplies as permanent. Therefore, it is reasonable to model price effects as though the price changes would be the same in all future periods. The supply equation, with all future prices set equal to one another, is

$$b_{i+1} = const + 0.7735 b_i + \frac{1.035}{(1 - 0.7367)} p_i^* = const + 0.7335 b_i + 3.931\, p_i^* \quad , \tag{3}$$

where p_i^* represents the steady-state, or long-run expected price of state i. For a 10-year adjustment period, the price elasticity of supply can then be represented by solving the above dynamic equation for 10 years and multiplying by the ratio of the steady-state price to inventory level:

$$\varepsilon_i^{lr} = \sum_{j=0}^{10} (0.7735)^j \frac{\partial b_{i+1}}{\partial p_i^*} \frac{p_i^*}{b_{i+1}} \ . \tag{4}$$

On average, for all hog-producing states, the elasticity at the sample means was estimated to be 4.2.

To estimate the effects of restricting AMA supplies on the hog market with the disaggregate model, it is necessary to obtain long-run elasticities (i.e., elasticities over a 10-year adjustment period) for each of the three markets: spot, contract, and packer owned. The short-run elasticities were assumed to be 3.02, 0.46, and 0.46 for the three markets, respectively. If we assume that each of these markets adjusts at the same rate over time, then we can obtain long-run elasticities for these three markets using the following relationships:

$$\varepsilon = k_1\varepsilon_1 + k_2\varepsilon_2 + k_3\varepsilon_3 \tag{5}$$

$$\begin{aligned} \varepsilon_1 &= \frac{\varepsilon}{k_1 + k_2(\varepsilon_2 / \varepsilon_1) + k_3(\varepsilon_3 / \varepsilon_1)} \\ \varepsilon_2 &= \frac{\varepsilon}{k_1(\varepsilon_1 / \varepsilon_2) + k_2 + k_3(\varepsilon_3 / \varepsilon_2)} \\ \varepsilon_3 &= \frac{\varepsilon}{k_1(\varepsilon_1 / \varepsilon_3) + k_2(\varepsilon_2 / \varepsilon_3) + k_3} \ . \end{aligned} \tag{6}$$

Each of the relationships in Eq. (6) is obtained by successively solving Eq. (5) for each of the elasticities of supply. If we assume that the relationship between the elasticities for each market is the same in the long run as in the short run, then we can use that information with the market shares to calculate long-run elasticities for each market. The mean cost shares are $k_1 = 0.13, k_2 = 0.67, \textit{and } k_3 = 0.20$. Thus, the long-run elasticities for the spot, contract, and packer owned markets are

$$\begin{aligned} \varepsilon_1 &= 7.8 \\ \varepsilon_2 &= 2.4 \\ \varepsilon_3 &= 2.4 \ . \end{aligned}$$

Appendix C: ARMS Data Set

In this appendix, we describe the ARMS data set used in conducting the analysis in Section 5. We obtained the data set from the *Agricultural Resource Management Survey Phase III, Hogs Production Practices and Costs and Returns Report, Version 4, for 2004*[1] (hereafter, ARMS III V4, 2004). ARMS Phase III data are collected at the farm level to obtain information about farm financial statements, production practices, and farm operators' household characteristics. Commodity-specific information is collected on a rotating basis. The special hogs survey is done every 6 years: 1992, 1998, and 2004. The data from different years do not form a panel; rather they represent independent cross sections. ARMS III V4, 2004 was collected from a series of interviews with 1,414 farm operators from 19 states.[2]

The ARMS III V4, 2004 survey responses consist of all types of hogs sold/marketed/removed during 2004. Because our major concern is with market hogs, defined as hogs sold directly for slaughter, we deleted the records for farmers who do not sell market hogs. This step reduced the sample size to 906. Market hog transactions are captured in three different channels: cash/open market sales, marketing contracts, and production contracts. Among 906 farmers who sell market hogs, a great majority used only one channel: 532 farmers used cash sales,

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[1] ARMS has been conducted by USDA's Economic Research Service (ERS) and National Agricultural Statistics Service (NASS) since 1975. More information and survey questionnaires can be found at http://www.ers.usda.gov/data/arms/globaldocumentation.htm.

[2] These states are AR, CO, GA, IL, IN, IA, KS, KY, MI, MN, MO, NE, NC, OH, OK, PA, SD, VA, and WY.

328 used production contracts, 21 used marketing contracts, 20 used a combination of marketing contracts and cash sales, and 5 used production contracts and cash sales. None of the respondents used all three channels at the same time. Because very few farmers use marketing contracts and marketing contracts and cash sales have many similarities, we combined them into one category, hereafter referred to as the cash/marketing channel.[3]

In Section P of ARMS, farm operators are asked to report the number of head of market hogs sold on the open market or under a marketing contract and the total dollar amount received for these sales. Using these responses, we constructed the quantities (q^1) and average prices (p^1) of market hogs sold through the cash/marketing channel. In the same section, farmers are asked to report the number of head of market hogs removed under a production contract. However, the final per-unit fee received under production contracts was reported in Section D, where the survey uses a different method of classifying hogs. Instead of market hogs, the survey uses commodity codes for the various types of hogs. For our analysis, we used *farrow to finish* (807), *grower to finish* (808), and *finisher* (809) hogs because all these contracts lead to the production of market hogs. Another problem is that for some observations the grower compensation fees are recorded on a per-animal space basis instead of on a per-head basis. In this case, we converted per-pig space fees into per-head fees using the available information in Section P of ARMS such that the quantities (q^2) and fees (p^2) for market hogs removed under production contracts are reported in the same units as prices and quantities in the cash/marketing channel.

We also extracted a number of variables describing farmers' socioeconomic characteristics. After deleting several outliers and accounting for missing observations, we ended up with 738 observations. Among these 738 farmers, 457 farmers use cash/marketing arrangements, 279 farmers use production

[3] The relatively small representation of marketing contracts does not seem to be in line with other publicly available sources of market hogs transactions data such as MPR. Personal communication with ERS and NASS personnel revealed that this phenomenon results because ARMS targets only farmers, whereas marketing contracts are largely used by integrators (not included in the survey) who contract the production of live hogs with farmers but use marketing contracts to sell live hogs to packers.

contracts, and only 2 farmers reported using both. We deleted these two observations because we believe that the simultaneous use of production contracts and other marketing arrangements may actually be prohibited by the majority of integrators or packers, so these two observations may be flawed.[4] The final sample consists of 736 farmers.

The variable names, descriptions, and summary statistics are reported in Table C-1. Two important features of the data set stand out. First, farmers who use cash/marketing arrangements are smaller and on average sell 4,098 hogs per year. Contract producers are larger and on average produce 8,680 hogs per year. Second, the average price recorded for cash/marketing arrangements is $119.75 per hog, while the average grow-out fee for production contracts is only about $13.41 per hog. This large spread reflects the differences in provision of inputs between the two different types of marketing arrangements and naturally leads to similar differences in production costs between the two AMAs.

Each observation in the ARMS survey has a different weight, or expansion factor. The weights reflect each observation’s probability of selection and can be used to prepare population estimates from the survey results. These weights are designed to expand certain variables such that they match the total industry numbers. For example, in the hog survey case, these expansion factors are calculated to correctly expand the inventory of all hogs and pigs on December 31, 2004, to match the number reported by NASS. The population estimate from ARMS is 57,851,816, and the total number of hogs and pigs on December 1, 2004, reported by NASS is 60,501,000.[5] Using these weights, we expanded the number of market hogs sold or removed in ARMS 2004 to obtain the population estimate of 82,012,081. This number can be compared with the estimates from several other sources. The number of market hogs sold in 19 states in 2004 reported in the National Pork Board Checkoff system is 91,537,136, the number of hogs sold in the MPR is 92,554,641, and the number of hogs slaughtered reported by NASS is 103,573,000.

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[4] This is most definitely the case in the poultry industry where production contracts explicitly prevent contract operators from keeping other birds on the farm.

[5] See Table 7–25 in *Agricultural Statistics*, United States Department of Agriculture, 2005.

Table C-1. Summary Statistics for the ARMS Data, 2004

Variable	Definition	Mean	Std. Dev.
cons	Constant	1	NA
farmtype	1 if hog operation is the main business	0.6277	0.4837
farmsize	Log of the acreage of the farm	4.6468	1.9650
east	1 if in NC, VA, and GA	0.2092	0.4070
midwest	1 if in Western Cornbelt	0.6821	0.4660
offincome	Log of off-farm income	3.5732	5.2006
age	Age divided by 10	5.0601	1.0623
educ	1 if at least has some college	0.5285	0.4995
nfamily	Number of family members	3.3166	1.7353
nfasset	Log of value of nonfarm assets	10.0015	3.9855
q^1	Number of hogs for cash/marketing farmer (10,000 head)	0.4098	1.4917
q^2	Number of hogs for production farmer (10,000 head)	0.8680	0.9330
p^1	Price per hog for cash/marketing farmer ($)	119.7453	21.5121
p^2	Price per hog for production farmer ($)	13.4087	6.4846

Note: Number of observations for q^1 and p^1 is 457, number of observations for q^2 and p^2 is 279, and number of observations for other variables is 736.

NA = Not applicable

To determine how well the expansion weights predict the number of hogs by states, we examined the three largest hog-producing states in the country: Iowa, North Carolina, and Minnesota. As Table C-2 indicates, after eliminating the outliers and the observations with missing values, the shares of expanded total hog sales in these three states are reasonably close to the National Pork Board Checkoff data. This comparison assures us that the sample used to estimate the farmers' supply of live hogs is not likely to suffer from sample selection bias.

Table C-2. Comparison of ARMS and National Pork Board Checkoff Data: Number of Hogs in Key States

	ARMS		
State	Expanded Total Before Eliminating Outliers (%)	Expanded Total After Eliminating Outliers (%)	National Pork Board Checkoff System (%)
Iowa	32.95	27.36	30.10
Minnesota	14.09	15.90	13.33
North Carolina	16.67	19.92	15.90

Appendix D: Estimation of Factor Demand Elasticities

To conduct the model simulations described in Section 5.3, we needed to estimate the industry inverse factor demand equations for live hogs through different channels (Eq. [5.21]) and the downstream consumer inverse demand (Eq. [5.22]). We obtained our data on the farmers' supply of hogs from ARMS 2004. Therefore, it would be most desirable to obtain factor demand elasticity estimates using the annual data. However, annual hog transactions data for different marketing arrangements are not available. Thus, we estimated the factor demand elasticities for different channels by aggregating the original *USDA/AMS Mandatory Price Reports* (MPR) daily data into monthly averages. Quantities are expressed as the monthly sums of slaughtered hogs, and prices are simple monthly averages of daily prices in dollars per head. The time period covered by the data is August 6, 2001, through February 22, 2006.

MPR records the transactions of *National Daily Direct Hog Prior Day—Slaughtered Swine* through six marketing arrangements:

- **Negotiated Purchase (MA1):** Cash or spot market purchase of hogs by a packer from a producer.
- **Other Market Formula Purchase (MA2):** Pricing mechanism is a formula price based on any market other than the market for hogs, pork, or pork products.
- **Swine / Hog Market Formula Purchase (MA3):** Pricing mechanism is a formula price based on a market for hogs, pork, or pork products.
- **Other Purchase Arrangements (MA4):** Other purchase arrangements include long-term contract

agreements; fixed price contracts; cost of production formulas; and formula purchases with a floor, window, or ceiling price.

- **Packer Owned (MA5):** Hogs that a packer owns for at least 14 days before slaughter.
- **Packer Sold (MA6):** Hogs that are owned by a packer and sold for slaughter to another packer.

Because the above channels do not match the definition of the alternative marketing channels in the ARMS data set, we combined marketing arrangements in the MPR to match the farmers' side data from ARMS. However, the exact correspondence is not possible to achieve. The reason for this is that ARMS data underrepresent the number of hogs coming from marketing contracts, and the MPR data underrepresent the number of hogs coming from production contracts. This is because ARMS surveys producers/farmers who predominantly use either cash markets or production contracts and rarely use marketing contracts. Marketing contracts are predominantly used by integrators who have production contracts with farmers and sell their finished hogs to packers using marketing contracts. The hogs produced under production contracts and sold to packers using marketing contracts do not appear under MA5 because this category only includes hogs owned by packers (both production contracts with independent producers or packer-owned farms). Instead, they appear under one of the marketing contracts categories (MA2–MA4).

Therefore, we grouped the marketing arrangements so that MA1 was kept by itself and MA2, MA3, MA4, and MA5 were grouped together into one category. Because the packer-owned hogs category (MA5) does not report prices (because these transactions are internal to the company), we used packer-sold (MA6) prices and paired them together with the packer-owned (MA5) quantities. Hogs recorded under packer sold (MA6) might come from all different channels (some of which could have been also bought on the spot market); thus, we excluded them from either of the two groupings. Because MA6 amounts to only 2.11% of the total hogs slaughtered in 2004, the potential error appears to be quite small. When creating the quantities and prices for the second channel (MA2+MA3+MA4+MA5), we took the sum of quantities from each channel and computed the weighted average of the prices using the quantities as weights. Finally, the correspondence with the supply side of the model is established by matching MA1 with the joint cash and marketing contracts arrangements (d = 1) and (MA2+MA3+MA4+MA5) with the production contracts arrangements (d = 2).[1]

To estimate the system of two factor inverse demand equations and one downstream consumer inverse demand equation, we needed to address the following two issues: (1) accounting for the endogeneity of the prices and quantities and (2) identifying the demand functions rather than supply functions. Carefully chosen instrumental variables resolve these two issues. We use live hog supply shifters in all three equations. Thus, the candidates for instrumental variables are variables that affect the live hog production costs including price of corn (P_{corn}), price of soybean meal (P_{sbm}), price indices of natural gas (P_{ngas}), price index for gasoline (P_{gas}), and price of feeder pigs ($P_{feedpig}$).[2] These variables can be also viewed as supply shifters for pork because they affect packers' demand for live hogs, which is closely related to the supply of pork.

We obtained the data series for the instrumental variables from publicly available sources. The data on feeder pig prices were obtained from the MPR (http://mpr.datamart.ams.usda.gov). Prices of corn and soybean meal were obtained from the Commodity Research Bureau (http://www.crbtrader.com/). The gasoline price index was obtained from the Bureau of Labor Statistics, U.S. Department of Labor (http://www.bls.gov/).

The 2SLS estimation results are summarized in Table D-1. In conducting the estimation, we imposed the restriction of the equal cross elasticities of the two channels in the inverse factor demand equations. We also tried different combinations of five instrumental variables. The combinations of instruments {P_{corn}, $P_{feedpig}$, P_{gas}} yield the smallest mean squared error, the smallest variance of individual parameter estimates, and the best goodness of fit. All the parameter estimates have the correct signs, though some of them are not significant.

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[1] The other possibility would be to match (MA1+MA2+MA3+MA4) with d = 1 and MA5 with d = 2. However, the error committed in this matching is, in our opinion, larger, and the estimation of the factor demands produces unreasonable results.

[2] The price of feeder pigs would be an endogenous variable if the system of equations consisted of both live hog supply and demand because most farmers who supply live hogs also supply feeder pigs. However, our current model consists of only factor demand equations; hence, feeder pig price is a valid instrument.

Table D-1. Estimation Results for Factor Demands and Pork Demand

Variable	Estimate	t-stat	Variable	Estimate	t-stat	Variable	Estimate	t-stat
	$\overline{p}^{cash}$			$\overline{p}^{production}$			$\overline{p}^{pork}$	
α_0	36.923	3.73	β_0	16.168	1.36	γ_0	22.558	1.21
α_1	–1.477	–3.29	β_1	–0.874	–2.56	γ_1	–0.927	–2.26
α_2	–0.874	–2.56	β_2	–0.091	–0.16	γ_2	–0.464	–0.47
α_3	0.449	1.31	β_3	0.502	1.97	γ_3	0.333	1.36
R^2	0.584		R^2	0.575		R^2	0.25	

Note: $\overline{p}^{cash}$ is average prices packers pay for live hogs under cash/marketing contract arrangements, $\overline{p}^{production}$ is the average price for live hogs under production contracts, and $\overline{p}^{pork}$ is the average price of pork in the downstream market (see Eq. [5.23]).